

UNITED STATES AIR FORCE ARMSTRONG LABORATORY

Tools Deployment Strategy for the Implementation of Integrated Product and Process Development (IPPD) in Science and Technology (S&T)

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FOR THE COMMANDER


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Preface

Battelle Memorial Institute and James Gregory Associates Inc. in support of the Supportability Investment Decision Analysis Center (SIDAC) performed this effort, under Subtask 11 of Task Order 123 of Air Force Contract Number F33657-92-D-2055.

This effort surveyed the state-of-the-art of commercial-off-the-shelf business-process support tools in late 1996 and early 1997. It then recommended strategies for tool development and deployment to effect process improvement in the Air Force S&T community. It represents only a snapshot of a rapidly changing commercial market. As such, it makes no long-term recommendations for tool selection, but highlights tool features and capabilities whose development warrants continued monitoring. It also recommends areas of further Government research, which could augment commercial developments in meeting Air Force needs.

To determine required tool capabilities, this effort included extensive interviews with program managers at four Air Force laboratories. The interviews, in essence, asked the participants to describe their needs for tools to do business in ways in which they had yet to use or study. The interviews served as much as an education in IPPD for them as it did as an information source for this study. The IPPD initiative is, in part, an attempt to bring more standardization and repeatability to the management of Air Force research and development. Yet research and development is a highly creative and subjective process. The general attitude of the participants could be described as enthusiastic for the opportunity to better document R&D decisions and rationale; and to better communicate between team members, through the chain of command, and during phase transitions. At the same time, their attitude was generally skeptical about how well R&D decision-making could be reduced to business formulas. A tool is only as good as the data it uses, and data often comes from personal judgment when exploring the unknown. Other concerns of the participants included the resources required to procure, maintain, and train on the tools.

The IPPD initiative will effect such a culture change in the AFMC S&T community that the tools used to implement it will in large part determine whether it is embraced positively or negatively. The long-term relevance of this study is, perhaps, the recording of the participants' reactions to each of the tool areas to which they were introduced. This report captures those reactions formally in lists of "major" and "core" features desired for the tools, and less formally but more informatively by documenting their comments to the "warm-up" questions.

Executive Summary

The purpose of this task was to identify, prototype and demonstrate tools and methods that support the AFMC/ST Science and Technology (S&T) Integrated Product and Process Development (IPPD) initiative. This effort was intended to provide critical research and development to establish the viability of a tools development strategy. The intent is to deploy Commercial-off-the-Shelf (COTS) software products that will aid the S&T community in implementing the IPPD strategy and, in turn, reduce program management and operation costs, particularly in the 6.3 demonstration phase. The assessment looked at tools in four areas:

1. (Technology) Requirements Collection, Organization, and Analysis;
2. (Value Judgment via) Group Consensus;
3. (Program Management) Workflow; and
4. (Design) Value Analysis.

This effort had three general objectives: (1) Gather user needs for tools to support the implementation of the IPPD process. (2) Provide a market assessment to determine whether commercial tools exist that could support these needs. (3) Recommend a tools development strategy for deploying tools throughout the Air Force S&T community.

The first objective of this effort was to gather user needs for tools and methods to support IPPD implementation. The approach chosen to accomplish this objective was an interview methodology using Ventana GroupSystems software. A two-day structured interview was developed that included an introduction to the S&T IPPD process and segments for each of the four tool areas being researched. Interviews were conducted with Wright Laboratory, Armstrong Laboratory, Phillips Laboratory, and Rome Laboratory personnel. Program managers from various S&T programs participated in the interviews and provided a wealth of information to the research team.

Through the use of GroupSystems, the structured interviews were exchanges of information between the research team and the participating program managers. Specifically, the research team first presented information to the participants on the S&T IPPD process and then on each of the tool areas being researched. After each presentation segment, the participants were asked to provide feedback on the information they had just received. Throughout the entire interview, the participants were also able to enter their thoughts and comments about IPPD or relevant subjects into the system. The GroupSystems software captured all of the input in electronic form.

The second objective of this effort was to determine if commercial tools exist that could support the user needs identified during the interviews. The assessment showed that tools are available which could be tailored to support the process in all areas except value analysis. That tool area requires a core, integrating *toolkit* that could interface to a variety of design and analysis applications.

This report presents the results of the interviews and the market analyses for the four tool areas. It became clear from the data that users' needs vary and that no single tool in any area is likely to satisfy the needs of every program. However, it was also clear from the data that users share many needs, and this commonality represents core capabilities that could be used as a starting point for selecting tools.

No recommendations were made for the use of specific tools in any area. Rather, the research findings are presented in a manner that allows program managers to select tools based on their particular needs.

The third objective of this effort was to recommend a tools development strategy for deploying tools throughout the S&T community. As such, this report is not a software development plan, but a strategy for selecting tools, customizing them, and integrating them over time into specific S&T programs having specific objectives. The essence of the strategy is:

- Select pilot programs in which to first implement the S&T IPPD process.
- Minimize the commitment to customize or combine tools until the need is imminent in an S&T program.
- Monitor market development regarding the key features and capabilities identified by users during the interviews of this study.
- Seed prototyping software development in value analysis because the marketplace is only now recognizing this tool area as a potential product category.
- Encourage and participate in standards development, particularly in the areas of web-enabled workflow, requirements analysis, and security.
- Form a Tools Working Group to track, assess, and report on tool developments as related to the S&T IPPD process.

The strategy delineated in this report represents the first step in deploying tools and methods to assist program managers in implementing the S&T IPPD process. By employing IPPD principles and practices, the S&T culture can move away from the historic performance-at-any-cost approach to technology development and application, toward a new, more cost-effective and risk-managed approach.

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1. Introduction

1.1 Background

The Science and Technology (S&T) Integrated Product and Process Design (IPPD) initiative was launched in 1993 at the direction of AFMC/ST. The fundamental goal of this initiative is to use IPPD principles and practices to better leverage S&T development efforts. The initiative intends to move the S&T culture away from the historic performance-at-any-cost approach to technology development and application toward a new, more cost-effective and risk-managed approach.

The IPPD initiative is aimed at making technology more affordable. The objective is to ensure that only the highest value technology products are implemented into Air Force weapon systems and their support infrastructure. The initiative, therefore, seeks to make IPPD a part of everyday life in the Air Force S&T community so that manufacturing-process issues and life-cycle-support issues are routinely balanced with product-performance potential, much earlier in the technology-development cycle.

The S&T community includes AFMC/ST, The Air Force Office of Scientific Research (AFOSR), Armstrong Laboratory (AL), Phillips Laboratory (PL), Rome Laboratory (RL), and Wright Laboratory (WL).

In the past, IPPD has often been ignored or ineffectively included in S&T programs due to factors such as (1) the emphasis on performance and innovation over cost; (2) the attitude that implementation costs were the customers' problem; and (3) the lack of IPPD training, methods, and tools available to S&T program managers. Therefore, the S&T IPPD initiative is focused on overcoming these deficiencies. The immediate users of the S&T IPPD process will be the Air Force S&T community, and the ultimate beneficiaries will be the S&T customers in the Air Force operational commands and support infrastructure.

1.2 Purpose

The purpose of this requirements-definition-and-tools-deployment strategy is to provide an overall strategy for identifying and deploying tools to support S&T IPPD implementation. The intent is to deploy Commercial-Off-The-Shelf (COTS) software products that will aid the S&T community in implementing the IPPD strategy, particularly in the 6.3 demonstration phase, and, in turn, reduce program management and operation costs. As such, this report is not a software development plan, but a strategy for selecting tools, customizing them, and integrating them over time in the context of specific S&T programs which are trying to achieve particular objectives.

The four tool areas researched were:

1. (Technology) Requirements Collection, Organization, and Analysis;
2. (Value Judgment via) Group Consensus;
3. (Program Management) Workflow; and
4. (Design) Value Analysis.

The first objective of this effort was to gather user needs for tools and methods to support 6.3 program managers in the implementation of IPPD. The approach chosen to accomplish this objective was an interview methodology using Ventana GroupSystems software. A two-day structured interview was developed that included an introduction to the S&T IPPD process and segments for each of the four tool areas being researched.

The research team believed that in order to reach the first objective, the interviews would have to be information-sharing sessions. Clearly, before the program managers could provide their needs for tools and methods to implement the S&T IPPD process, they would have to understand the process. Through the use of Ventana GroupSystems, the interviews were an exchange of information between the research team and the participating program managers. Specifically, the research team first presented information to the participants on the S&T IPPD process and then on each of the tool areas being researched. After each presentation segment, the participants were asked to provide feedback on the information they had just received. Throughout the entire session, the participants were also able to enter into the system their thoughts and comments about IPPD and relevant subjects. The GroupSystems software captured all of the input in electronic form.

The research team believed that this interactive approach to gathering needs for tools and methods offered several benefits. First, the opportunity to expose program managers to the S&T IPPD process would enhance the overall S&T IPPD initiative. Second, this method of collecting user needs would increase user buy-in of the tools recommended for use and of the S&T IPPD initiative itself. Third, the information collected would help to support the conclusions of the research team regarding features and capabilities that tools should have in order to aid IPPD implementation. Finally, the GroupSystems software provides the capability to capture all of the user interaction electronically, thereby providing a complete transcript of the interviews -- a capability usually not possible with traditional minutes taken by a scribe.

Interviews were conducted with the organizations shown in table 1. The Air Force Technical Manager arranged the interviews with appropriate S&T program managers and representatives from laboratory management.

**Table 1. Organizations Interviewed
for IPPD Tool Requirements**

Organization	Interview Date
Wright Laboratory	5 - 6 June 1996
Wright Laboratory	19 - 20 June 1996
Armstrong Laboratory	14 - 15 August 1996
Phillips Laboratory	18 - 19 September 1996
Rome Laboratory	16 - 17 October 1996

The second objective in this research was to conduct a market assessment to determine whether COTS software products were available to support the implementation of IPPD. Once the user needs were collected, the research team was able to use the data to determine evaluation criteria for these products. It must be stressed that the research team strongly believed it to be unlikely that a single tool from a tool area would satisfy all research needs. In fact, the results of this task show that each group of users has different needs depending on the type of research being accomplished and the maturity of the technology being developed. Therefore, no pretense was made in this report to suggest specific tools for use by program managers. Rather, this effort has identified candidate tools in each of the four areas and evaluated them against the needs identified in the structured interviews. The results are presented so that program managers can see which tools satisfy their particular needs at any given time.

1.3 About This Report

This document is organized into five sections.

This section, Section 1.0, has provided background and introductory information about this effort.

This section also described the methodology chosen to conduct this research and the rationale of the research team for choosing it.

Section 2.0 describes the approach and protocol used to conduct the structured interviews at the laboratories. Included is a discussion of the interview agenda, a summary of the presentations, and a description of the scenario-based approach used to illustrate the S&T IPPD process.

Section 3.0 presents the results of the structured interviews and the market assessments for each of the four tool areas.

Section 4.0 makes recommendations for future tools and methods development.

Section 5.0 summarizes the major findings of this report.

2. Approach and Interview Protocol

This project set out to ask program managers what kinds of tools and methods they would need to implement a process they had yet to use or study. The approach, therefore, had to provide a substantial amount of information about the IPPD process, itself, to laboratory program managers. As a result, an interview protocol was developed that included a series of moderately in-depth presentations. The approach was to provide sufficient information about IPPD in digestible portions, one piece at a time, so that the attendees could focus on the tools and methods needed to implement each portion.

In order to facilitate the interviews, the research team used Ventana GroupSystems software. This groupware system consists of software that runs simultaneously across a set of laptop computers. The typical setup supports up to ten participants along with a facilitator and a technographer. The technographer runs the system, sends appropriate information to the participants' computers, and captures salient discussion information that is not being entered by any of the participants. The software provides for "comment cards," which allow participants to type in questions or comments at any point during the presentation. The comment cards are structured topically and are usually titled with either a question or the functional area on which feedback is being solicited. As participants enter and submit their comments, everyone linked with the system can see the comments. Each comment is numbered for tracking, but its author remains anonymous. Participants can respond to questions or comments by referring to the comment number or by posting a "yellow sticky" to the left of a comment. The technographer controls what the participants can see and do at any time. The facilitator guides the participants through the interview segments and the use of the software.

This section presents the organization and content of the interview protocol. First, the interview agenda is reviewed. The remaining paragraphs cover in detail all of the presentations given during the two-day interview sessions and a discussion of the effectiveness of this approach.

2.1 Interview Agenda

The research team constructed the interview protocol around the premise that the interviews would be information exchanges between the team and the participants. As noted above, the participants had little exposure to the S&T IPPD process; thus, a moderately in-depth introduction was the first part of the interview. As with all the presentations, the GroupSystems software was available for the participants to enter comments they deemed to be appropriate. After the S&T IPPD process overview, each tool area was covered. The general format of the agenda for the tool area presentations was as follows:

1. Present information on the tool area and its relationship to the S&T IPPD process;
2. Present a conceptual demonstration of how a tool might aid the S&T IPPD process;

3. Ask the participants a series of “warm-up” questions to stimulate thinking about their needs for a tool in this area;
4. Solicit feedback in terms of needs, features, or capabilities that a tool in this area should have; and
5. Review and comment on the resulting list of needs, features, and capabilities. Prioritize these using a voting process.

The research team had planned to adjust the interview agenda as they analyzed participant feedback from each session. This they did, particularly with the warm-up questions and the tools presentations.

The warm-up questions were changed after the first two interviews because some of the questions were too leading and others simply failed to elicit the desired information. These changes were not seen as a hindrance to the research objectives since the warm-up questions were a precursor to the heart of the effort -- soliciting user needs for specific features of the tools.

As a result of participant feedback, the presentations evolved to include a conceptual demonstration of what tools might do to aid S&T IPPD implementation. The conceptual demonstration was an end-to-end scenario that illustrated potential use of tools in all of the tool areas. The scenario was based on a hypothetical 6.3 (Advanced Technology Development & Demonstration) program called the *Federated Data Management for Air Logistics Centers* (FDM/ALC). It contained both hardware and software project elements. The notion was that the Air Force needed portable, laptop-computer-like units that could provide flight-line maintenance technicians with all of the maintenance information they required for a given aircraft, in “real time” and while physically on the flight line. The scenario contained four parts designed to illustrate each of the tool areas. It was implemented using an World Wide Web server and browser loaded onto a laptop PC.

The following paragraphs describe the content of each of the presentations. A description of the scenario for each tool area is also given.

2.2 S&T IPPD Process Overview Presentation

This presentation consisted of a review of the overall S&T IPPD Process and motivation for its implementation. Included was a review of the AL Tools and Methods task within the initiative and an introduction to the S&T IPPD process model.

2.3 (Technology) Requirements Management Presentation

The requirements management presentation addressed the first two activities of the S&T IPPD process model (Define Requirements and Establish S&T Exit Criteria). The presentation focused on the application of Quality Function Deployment (QFD) and the House Of Quality (HOQ) to S&T needs.

Requirements Scenario. The requirements management portion of the scenario illustrated how a program manager could respond to a short suspense “crisis” by rapidly tracking down and compiling information to justify key program decisions that were made earlier in the program’s life, prior to his or her own tenure with the project. This portion of the demonstration made use of a workflow-tool interface which was modeled after the interface to Metro, a workflow tool by Action Technologies. It also demonstrated an HOQ with “animated” call-up windows (implemented in ActiveX). It did not illustrate the original capture and organization of the requirements. This portion of the scenario was the most effective of the four areas for two reasons: (1) participants could understand in very concrete terms how requirements analysis tools could help them, and (2) they could directly relate the scenario to their own S&T programs.

2.4 (Value Judgment via) Group Consensus Presentation

The group consensus presentation addressed the overall need for consensus activities at various points throughout the S&T IPPD process, as well as an approach for achieving group consensus.

Group Consensus Scenario. The group consensus portion of the scenario illustrated an approach to determine which laboratory mission priorities should be addressed by the FDM/ALC project. The technique that was illustrated is called *Successive Proportional Additive Numeration* or SPAN, and involves the “blind” assignment of “points” or “votes” among the decision-making participants followed by a voting process. This portion of the scenario appeared to be the least effective because, to the research team’s surprise, participants had trouble relating to laboratory “mission priorities” and there appeared to be some concern that tools and techniques such as SPAN might dilute program manager authority and his or her ability to direct the effort. (On the contrary, where such tools have been implemented, they tend to reinforce program manager decisions rather than dilute program manager authority.)

2.5 (Design) Value Analysis Presentation

The value analysis presentation addressed activities 3 and 4 of the S&T IPPD Process (Determine Technology Alternatives and Perform Value Analysis). This area was the most challenging because it is central to the notion of applying variability metrics to determine the relative value of competing technologies.

Value Analysis Scenario. In this portion of the scenario, the participants were stepped through an illustrative S&T value scorecard. There was insufficient time during the interviews to bring

the participants down to the level of the design worksheets, from which the numbers in the value scorecard usually derive. As a result, there was some angst with respect to how the numbers in the scorecard would be generated in an actual program.

2.6 (Program Management) Workflow Presentation

The workflow presentation addressed issues in the underlying workflow infrastructure required for effective management of complex programs with distributed Integrated Product Teams (IPTs). This presentation helped participants understand the differences between *workflow*, *groupware*, and *group consensus* tools, as explained in section 3.3.

Workflow Scenario. The IPPD process model's concept of workflow and interaction with a "control center" permeated the entire scenario demonstration. This concept "stole the thunder" from the actual workflow demonstration. Workflow was the second most difficult tool area for which to elicit meaningful requirements. First, participants were not familiar with the concept. Second, workflow unnecessarily complicates the management of simple programs run by a few collocated people. For many laboratory programs, it would be "overkill." Third, most of the participants have little experience on programs that require a high degree of integrated interaction, including automatic tasking and tracking among members of a distributed IPT. Nevertheless, many participants saw significant potential value for workflow tools, but viewed their implementation as a long-term proposition.

2.7 Effectiveness of Approach

The IPPD-process-overview portion and the requirements-management portion of the interview were very effective at communicating the tasking that S&T managers will receive during IPPD. Participants gained a sufficient understanding to effectively generate and prioritize their needs for supporting tools.

The value analysis portion of the interview provided a good overview of this tool area. Participants viewed the value scorecard as a good thing, but the necessary details were too overwhelming to enable effective generation of user needs. A positive side effect of the interview was that many participants wanted to take the Design for Six Sigma Manufacturing (DSSM)/Capstone Course and devote the time necessary to more fully understand this area. The group-consensus portion of the interview never worked well. The user needs generated by the participants were based primarily on the features and capabilities that the research team had provided. The participants liked the tool they experienced (i.e., Ventana GroupSystems), and many thought that the approach was effective for brainstorming activities. However, the participants did not understand the need for consensus activities in the S&T IPPD process outside of brainstorming. The research team, therefore, concluded that many of the techniques available to drive a group toward consensus must be directly experienced, rather than briefed, for comprehension.

The workflow portion of the interview was another area that was too complex for the uninitiated to sufficiently grasp to delineate their needs for features and capabilities. Most participants saw workflow tools simply as project management tools, and wanted to compare workflow to Microsoft Project. In fact, it appears that tools like Microsoft Project are a step up from what many program managers currently use.

3. Results by Tool Area

3.1 (Technology) Requirements Management

A requirements-management tool, in broad terms, provides for the collection, organization, and analysis of customer-derived requirements for a project and technology application. Such a tool could also be used in performing correlation analysis between customer requirements and engineering design criteria.

Interview participants were first given the presentation described in paragraph 2.3 covering this tool area. This briefing served as a high-level introduction to the capabilities of requirements management tools, the categories of this type of tool (e.g. Quality Function Deployment (QFD), Systems Engineering), and products and trends in tool development.

A major objective of the interviews was to query the participants about the features these tools should possess in order to assist in implementing IPPD. Preceding formal data collection, warm-up questions were asked of the group to stimulate thoughts about their needs for tool capabilities. The following paragraphs present the results of the structured interviews and the tools identified as candidates to provide requirements management capabilities. The tools are then evaluated against the needs identified by the users during the interviews. Also included are a discussion on market trends related to requirements management tools, and recommendations for future development in this tool area.

3.1.1 Interview Results

The majority of attendees were strongly interested in the requirements-management tool. The disjointed and difficult task of capturing and managing requirements for technology development projects can be overwhelming. The deployment of an automated tool could serve to ease the process and allow for the instant generation and manipulation of data.

A set of warm-up questions was developed to stimulate the participants' thinking about the features and capabilities of requirements management tools. During the successive interviews, this set of questions evolved based on participant feedback and the research team's review of the answers elicited. The final set of questions and representative responses are summarized below.

How does your organization capture and manage project requirements, and what tools and methods have proven helpful?

- Projects are defined through bench scientist research and contracted front-end analysis.
- Typically, by identifying potential customers and holding face-to-face meetings.

- In general, we do not systematically capture and manage to a set of project requirements.
- We use ad-hoc tools that are rarely beneficial to the “gaining” program.
- This is done by informal group consensus among those involved in developing proposals and Statements Of Work (SOWs). While the process is generally extensive and well done by the time it's finished, it is haphazard, unintegrated, and not always well documented.
- Unfortunately, few tools and methods have proven effective. A tool like the one we are using might help facilitate reviewing and responding to user requirements with our plans’ office.
- Mostly manually! Lists of requirements versus solutions in a spreadsheet is the most sophisticated case. Generally, requirements have been few and at high level, with only a few possible technical approaches considered.
- Meeting minutes, people’s notes, red-lined documents, action items, etc.

In some cases, structured techniques were noted as being used for capturing requirements. These included IDEF modeling, QFD, site visits, electronic mail (e-mail), interview sessions, Joint Application Development (JAD) sessions, brainstorming sessions, and general process approaches (that start with analyzing a set of determined needs and end with an established list of project features, constraints, assertions, and priorities).

Is the customer integrated into the process of gathering requirements? How?

- We have started integrating customers. However, there is no formal method.
- As much as possible, normally through the Integrated Product Team (IPT).
- There is no way to define requirements without the customer. (Lots of travel, e-mail, fax, and video/telephone conversation are used.)
- They are usually invited to participate in the Technology Transition IPT. (They may not be an active participant – but may review what is generated.)
- If the customer is paying for the activity, s/he may be more pro-active.

Was the scenario helpful or not helpful in understanding requirements management? Why?

- Yes. You can see how to access the information you need, as long as you can maneuver from one concept to the next without getting lost. Always have that big picture available.
- Yes. The scenario was useful and I hope to see how 6.2 efforts might also be addressed.

- The House Of Quality (HOQ) process is not much different from a file plan, in that it is only as good as the discipline followed when using it. If the discipline isn't followed carefully, the HOQ is essentially worthless.
- One of the most interesting aspects of the tools demonstrated is the permanent capturing of decision logic and supporting studies. This sure beats digging through file cabinets after someone moves to another job!

Would the demonstrated approach to requirements management be useful to you in your projects? Please explain.

- I'm not sure my staff could understand the complex subject matter. I also was looking for the Mission Need Statement (MNS) or the Operational Requirements Document (ORD) developed by the customer. It wasn't in the scenario but should have been.
- Yes, if my customers were more directly involved in stating and reviewing their requirements. Unfortunately, most requirement statements I see are generated and/or interpreted by headquarters staffs. Consequently, I spend a great deal of time verifying the needs statements I receive from my plans office with my customers located in the field.
- Yes. This is a formalization of the design process that is usually (always?) done anyway, and would be useful in saving time, catching gaps and errors in the design, and documenting the decisions.

What key elements of requirements definition or analysis have we missed?

- The mission area planning (MAP) process.
- What is needed in your software support tool for the HOQ documentation process is something to highlight everything that is possibly affected by every change that is made to the HOQ. In other words, everything that is linked to a single location on the HOQ, or everything that is linked to a location that is linked to the location where the change was made, or to a location that is linked to a location that is linked to a location ... In other words, you have to be able to see the total impact of each change that is made to the HOQ. This is what often fails in the requirements definition process. People lose track of why they didn't go in that direction in the first place.
- You have missed the possibility of encountering multiple customer groups with conflicting requirements. We need assistance in reaching consensus among them to produce a final requirements priority list.
- You missed the operators' requirements documents and the test organization coordination.

From these participant comments, the following general observations can be made:

1. Requirements management in 6.3 programs is mostly a manual, unstructured process.
2. Program managers attempt to keep customers involved but generally have no structured approach to do so.
3. QFD and the HOQ are viewed as productive methodologies.
4. Program managers are very concerned about requirements traceability, linkage, rationale, and supporting material.
5. Program managers are interested in access to official requirements documents generated by customers such as Mission Need Statements (MNSs) and Operational Requirements Documents (ORDs).

Bottom Line: These comments highlight the need for a more disciplined, structured approach in managing requirements in research programs. Furthermore, a tool to help implement such a process is needed.

The information gathered during this question-and-answer session set the stage for the next step in the interview process -- building a list of desired capabilities for a requirements management support tool.

3.1.2 User Needs for Requirements-Management Tools

In the first interview, a blank page was provided in the GroupSystems software for the interviewees to enter features and capabilities desired in a requirements-management tool. In the rest of the sessions, it was determined a more useful approach would be to provide the participants with a pre-established list of features (with definitions) for their comment and refinement. The pre-defined list of features and capabilities for a requirements collection, organization, and analysis tool was:

- 1. Requirements Definition, Decomposition, and Allocation:** The tool should provide significant automation support to the process of creating, storing and displaying original and derived project requirements from top-level user requirements down to detailed design and performance requirements. This includes the ability to designate requirement categories, and to link requirements to other types of data elements/objects such as verification methods. The tool should provide the capability to provide rationale for requirements.
- 2. Requirements Traceability:** The tool should make it easy to follow linked requirements (or other objects or elements) to parents, children or siblings, providing a clear, multilevel view of their traceability. Graphical depiction is preferable.
- 3. Requirements History:** The tool should maintain the change histories for all database elements/objects, preferably automatically as the changes are made. The tool should also provide the ability to capture rationale for the changes.

4. Identification and Tracking of Program Issues: The tool should permit the input of programmatic issues and the association of those issues with the appropriate system elements (e.g., requirement, function, interface, etc.). It also should provide a mechanism for specifying the status of each issue, capturing the eventual resolution of each issue, and capturing the effects of that resolution, such as additional or amended requirements.

5. System Architecture Definition: The tool should support the definition of system functions, interfaces, and components. It should provide the means to allocate functions to system components. It should provide a hierarchy or other graphical representation of the component structure.

6. Standard Document/Query Generation: The tool should have the capability to easily generate, on demand, hardcopies of standard reports (e. g., database listings, traceability reports, orphan/widow reports, etc.) and queries. The ability to create or import graphs and tables is desired. A variety of standard output formats is also desired, including ASCII and Microsoft RTF.

7. Custom Document/Query Generation: The tool should allow creation of custom reports such as individual traceability reports, element description reports, custom queries, etc., without specialized tool knowledge or training. Word-processor style functions are desired. The tool should provide the ability to create templates for use when creating standard documents.

8. User Interface: The tool should have a user interface that is intuitively easy to learn and operate. A Graphical User Interface (GUI) is preferable to a command line approach. The tool should support a wide variety of users.

9. Bridges to Other Support Tools: The tool should have well-defined, trouble-free interfaces to other commercial products, particularly the Microsoft Office suite of office support tools. It also should provide links to analysis tools, groupware, and the worldwide web (WWW). It should provide an ability to use multimedia.

10. Analysis: The tool should provide the capabilities to conduct trade studies, compare competing solutions, examine impacts of changes, verify test acceptance criteria, and prioritize requirements.

11. Configuration Management: The tool should have configuration management capabilities that allow establishment and control of baselines and versions of both requirements and documents. The tool also should provide mechanisms to route, track, coordinate, and incorporate changes to documents.

12. Reuse: The tool should provide the capability to reuse requirements sets, supporting documentation, etc. once they have been entered into the database. For example, if a requirements set has been established for a system or subsystem, this set could be used in the requirements identification of another system or subsystem without re-entering the data.

13. Interfaces to Other Activities: The tool should provide interfaces to other activities such as acquisition, procurement, etc.

14. Multi-User Support: The tool should support simultaneous database access by multiple users and provide the means to coordinate database changes to avoid conflicts.

15. Access Control: The tool should provide password protection and allow administrator assignment of read and write privileges to any portion of the main database for each user.

16. Security: The tool should provide some level of built-in support for databases in secure environments, such as automated security markings on displays and hard copies.

17. Cost:

- Initial Cost - Cost of software license, documentation, installation, and required support resources,
- Training Cost - Cost of any necessary vendor-conducted user training, and
- Recurring Cost - Yearly cost to keep license current and receive software updates.

18. Performance as Database Grows Large: The tool should accommodate large databases (>10,000 objects or records) with little or no performance degradation. Is there a practical limit beyond which the tool may become unusable?

19. Platforms Supported: The tool should be hosted on Windows, Macintosh, and UNIX machines.

20. Vendor Support: Vendor support should be accessible and provides timely, helpful answers to tool implementation problems. The vendor should offer a range of application support capabilities.

21. Maturity Indicators:

- The length of time the tool has been in the marketplace,
- The number of companies using the tool to support real programs including commercial programs, and
- The extent to which there have been known problems with the tool.

22. Database Tailorability/Extendibility: The tool should support tailoring and extension of the existing database structure to better conform to particular program terminologies and methodologies. Such tailoring and extension should not result in loss of any tool functionality.

23. Tool User Documentation /Training: The vendor should provide quality documentation with the tool. User manuals should be comprehensive, understandable, and include tutorials for beginning users.

24. System Modeling: The tool should provide the capability to create and execute the functional, data, and control flows of a system and its subsystems.

25. Capability to Show Process/Demonstrate Requirements: The tool should provide the capability to simulate the process or requirement that will be addressed. The simulation could be compared to the current environment in order to demonstrate potential improvements, cost savings, and process changes.

26. Requirements Sensitivity Analysis: The tool should allow exploration of “what if” scenarios with the requirements and their weightings to determine how the program may change with downstream requirements. The tool should save these 'what ifs' separately from the official set of requirements.

The participants were given the opportunity to comment on each of the above listed features and capabilities. They were also allowed to add or delete features and capabilities. Each interview arrived at a list of 25 to 30 features that the selected tool should have within its functional capacity. When the participants had finished editing and commenting on the list, a vote was taken to determine which features were most important. The voting results for all five interviews are shown in table 2. Desired features are lined up across the table so that it is easy to see the degree of consensus. Note that only the top twelve choices from each interview are shown. These are designated as “major” features.

The voting results shown in Table 2 reveal that there is a core set of features upon which most of the participants agreed for a requirements management tool. For the purposes of this analysis, a feature was considered as a “core” feature if it were rated as major a feature (i.e., ranked in the top 12) at least three times. Given this definition, the core features identified for a requirements management tool are:

1. Analysis
2. Configuration Management,
3. Identification and Tracking of Program Issues,
4. Multi-User Support,
5. Requirements Decomposition, Definition, Allocation,
6. Requirements Sensitivity Analysis,
7. Requirements Traceability,
8. Standard Document/Query Generation, and
9. User Interface.

The results also show that some features were only important to one of the participant groups. This supports the research team’s belief that every program will have different needs based on the maturity of its technology and on the type of research involved.

Table 2. Major Features Desired for Requirements Management Tools

Interview # 1 5 - 6 June 1996 Wright Laboratory	Interview # 2 19 - 20 June 1996 Wright Laboratory	Interview # 3 14 - 15 August 1996 Armstrong Laboratory	Interview # 4 18 - 19 September 1996 Phillips Laboratory	Interview # 5 16 - 17 October 1996 Rome Laboratory
	Access Control			
Analysis	Analysis	Analysis	Analysis	Analysis
Captures Expertise				
Configuration Management	Configuration Management	Configuration Management		Configuration Management
Cost				Cost
		Identification and Tracking of Program Issues	Identification and Tracking of Program Issues	Identification and Tracking of Program Issues
Interface to other Tools, e.g., charting tools				Interface to other Tools, e.g., charting tools
	Multi-user Support		Multi-user Support	Multi-user Support
Platforms Supported	Platforms Supported			
	Prioritization Capability			
Promotes Collaboration				
	Requirements Decomposition, Definition, Allocation	Requirements Decomposition, Definition, Allocation	Requirements Decomposition, Definition, Allocation	Requirements Decomposition, Definition, Allocation
		Requirements History	Requirements History	
Requirements Sensitivity Analysis	Requirements Sensitivity Analysis	Requirements Sensitivity Analysis	Requirements Sensitivity Analysis	
Requirements Traceability	Requirements Traceability	Requirements Traceability	Requirements Traceability	Requirements Traceability
Reuse			Reuse	
				Risk Management
Standard Document/Query Generation		Standard Document/Query Generation	Standard Document/Query Generation	
		System Architecture Definition		
	Tool User Documentation/Training			
User Interface	User Interface	User Interface		User Interface
	Vendor Support			

3.1.3 Market Assessment for Requirements-Management Tools

The following paragraphs summarize of the market assessment for requirements-management tools. First, the major features of interest are reviewed. Then, a summary is given of the tools available and how each tool supports the major features of interest. Next follows a discussion of market trends in terms of industry initiatives. Finally, recommendations are made for future enhancements of requirements-management tools.

3.1.3.1 Major Features of Interest

The major features of interest are those features that were ranked in the top 12 features at least one time during the interviews. Considering a feature major even if it was ranked in the top twelve features only one time supports the research team's belief that all programs are different and may require unique capabilities. These features became the focus of interest in the market assessment. They are:

1. Access Control,
2. Analysis,
3. Captures Expertise,
4. Configuration Management,
5. Identification and Tracking of Program Issues,
6. Interfaces to Other Tools,
7. Multi-User Support,
8. Platforms Supported: Macintosh,
9. Platforms Supported: UNIX,
10. Platforms Supported: Windows,
11. Prioritization Capability,
12. Requirements Definition, Decomposition, and Allocation,
13. Requirements History,
14. Requirements Sensitivity Analysis,
15. Requirements Traceability,
16. Reuse,
17. Risk Management,
18. Standard Document/Query Generation,
19. System Architecture Definition,
20. Tool User Documentation /Training,
21. User Interface, and
22. Vendor Support.

3.1.3.2 Requirements-Management Tool Candidates

The market assessment included identifying tools that could potentially support the features and capabilities listed above. Research of the market for requirements collection, organization, and analysis tools showed that the demand for and supply of these tools has increased dramatically in the last decade. Although systems engineering as a methodology has been around since the 1950's, only recently have computer technology advancements made it possible to provide the storage capacities and processing speeds necessary for automating systems engineering. Since the computer power is now available, software vendors have been offering more tools. Among the emerging automated tools are specialized requirements-management tools. These tools concentrate on capturing and managing requirements and producing requirements specifications. The focus of this tools search was to identify automated tools (either QFD or systems engineering tools) that support requirements management. The results of the search showed that automated tools are available to support both the QFD approach and the systems engineering process. Once identified, these tools could be evaluated in terms of how they satisfy the major features of interest shown in paragraph 3.1.3.1 above. The tools identified as potential candidates for requirements management are shown in table 3 along with relevant administrative information.

As shown by table 3, the market offers several requirements-management tools. Also, note that the tools vary in price from \$950 to \$50,000. This wide range in price is indicative of the robustness of the tools, as will be seen in the next paragraph.

3.1.3.3 Requirements-Management Tool Evaluations

Using the needs identified for a requirements-management tool and the list of COTS tools identified as potential candidates, an analysis was conducted to see which tools satisfied the needs identified during the interviews. No recommendation was made regarding which tools a program manager should use. This decision must be made by the program manager based on his/her program's particular needs.

Table 3. Requirements-Management Tool Candidates

Company	Product	Description	Price	Contact
Qualisoft	QFD Designer	PC Based. Automates QFD Methodology	\$975	4652 Patrick Rd. West Bloomfield, MI 48322 (810)645-2561
International TechneGroup Inc.	QFD/CAPTURE	PC Based. Automates QFD Methodology	\$950	(800)783-9199
Quality Systems & Software	DOORS (Dynamic Object Oriented Requirements System)	Requirements Management	\$5,000	11921 Freedom Dr. Reston, VA 22090 (703)904-4360

Table 3. (Concluded)

Company	Product	Description	Price	Contact
Marconi Systems Technology	RTM (Requirements Traceability and Management)	Requirements Management	\$20,000	1861 Wiehle Ave. Reston, VA 22090 (703)736-3525
Teknowledge Corporation	ProductTrack	Requirements Management	\$50,000 10 user licenses	1810 Embarcadero Rd Palo Alto, CA 94303 (415)424-0500
TD Technologies	SLATE (System Level Automation Tool for Engineers)	Requirements Management	\$10,000 to \$18,000	6140 Parkland Blvd. Mayfield Heights, OH 44142 (216)460-4700
Mesa Systems Guild	Cradle SEE	Requirements Management	\$14,000	60 Quaker Lane Warwick, RI 02886 (401)828-8500
Vitech Corporation	CORE	Requirements Management	\$8,000	2070 Chain Bridge Rd Suite 105 Vienna, VA 22182 (703)883-2270
Ascent Logic Corporation	RDD-100	Requirements Management	\$12,000	180 Rose Orchard Way San Jose, CA 95032 (408)943-0630
Compliance Automation, Inc.	VITAL LINK	Requirements Management	\$5,690	17629 El Camino Real Suite 207 Houston, TX 77058 (713)486-7817
Teledyne Brown Engineering	Xtie-RT	Requirements Management	\$6,000 first seat, \$1,499 each add.	300 Sparkman Dr. NW P.O. Box 070007 Huntsville, AL 35807
Requisite, Inc.	Requisite	Requirements Management	\$795	4720 Table Mesa Dr. Boulder, CO 80303 (303)499-9177
Armstrong Laboratory	Requirements Analysis Process in Design-Weapon Systems (RAPID-WS)	Requirements Management	N/A	AL/HRGA WPAFB, OH 45433 (513)255-8502

Evaluations of the requirements-management tools were accomplished by reviewing vendor literature and by reviewing other tool reviews by third parties such as the International Council on Systems Engineering (INCOSE) and the Aerospace Corporation. In some cases,

demonstration copies of the tools were obtained and reviewed. In other cases, vendors demonstrated the tools. In two cases (SLATE and RAPID-WS), hands-on use of the tools was possible.

The methods of tool evaluation are important for two reasons. First, the “vaporware” syndrome prevalent today may cause vendors to exaggerate their products’ features beyond their true capabilities. Second and perhaps more importantly, an evaluation of software based only on literature and demonstrations may not be as thorough as it should be. Even though the literature contains words and language the reviewer thinks he/she understands, the possibility exists for miscommunication. Two outcomes of a miscommunication are possible. One is that the reviewer believes the tool provides a certain feature when it doesn’t. The other is the reviewer believes the tool doesn’t provide a certain feature when it does. Either outcome should be mitigated by further evaluation via hands-on use.

The results of the evaluations are presented in table 4. Each candidate tool was evaluated against the major features identified in the interviews. The table should be interpreted as follows:

1. ● indicates the tool offers strong support for the feature,
2. ◐ indicates the tool offers medium support for the feature,
3. ○ indicates the tool offers only limited or weak support for the feature, and
4. A blank cell indicates the tool offers no support for the feature.

Program managers need to remember the uncertainty associated with the evaluation techniques discussed above when using table 4 to choose a requirements-management tool. Since the interviews supported the research team’s belief that all programs have unique needs, the approach of identifying candidate tools for further hands-on exploration by each program is preferable to that of recommending one tool for all programs.

3.1.4 Market Trends in Requirements-Management Tools

As mentioned above, more vendors are offering requirements-management tools. As the tools become more sophisticated, many companies are offering modular products. For example, many of the high-end systems-engineering-tool vendors offer their products in stand-alone modules that separate the functions of systems engineering into requirements management, modeling, systems design/engineering, and document management. This separation can be beneficial to those users who are only interested in particular functions such as requirements management. The opportunity to buy additional modules as they are needed is also attractive.

Table 4. Requirements-Management Tool Evaluations

FEATURE EVALUATED	QFD Designer	QFD CAPTURE	DOORS	RTM	ProductTrack	SLATE	Cradle SEE
Access Control			●	●	●	●	●
Analysis	●	●	●	●	●	●	●
Captures Expertise			●	●		●	●
Configuration Management			●	●	●	●	●
Identification and Tracking of Program Issues			●	●	●	●	●
Interfaces to Other Tools			○	○	○	○	○
Multi-User Support			●	●	●	●	●
Platforms Supported: Macintosh							
Platforms Supported: UNIX			●	●	●	●	●
Platforms Supported: Windows	●	●	●	●	●		
Prioritization Capability	●	●	●	●	●	●	●
Requirements Definition, Decomposition, and Allocation	●	●	●	●	●	●	●
Requirements History	●	●	●	●	●	●	●
Requirements Sensitivity Analysis	●	●	○	●	●	●	●
Requirements Traceability	●	●	●	●	●	●	●
Reuse	●	●	●	●	●	●	●
Risk Management			○	●	○	●	●
Standard Document/Query Generation	●	●	●	●	●	●	●
System Architecture Definition			●	●	●	●	●
Tool User Documentation /Training	●	●	●	●	●	●	●
User Interface	●	●	●	●	●	●	●
Vendor Support	●	●	●	●	●	●	●

Level of Support: ● = Strong, ● = Medium, ○ = Weak, Blank = None

Table 4. (Concluded)

FEATURE EVALUATED	CORE	RDD-100	Vital Link	XTie-RT	Requisite	RAPID-WS
Access Control	○	●	●	●	●	○
Analysis	●	●	○	●	○	○
Captures Expertise		●	●			
Configuration Management	●	●	●	○	●	●
Identification and Tracking of Program Issues	●	●	●	●	●	●
Interfaces to Other Tools	●	●	○	○	○	○
Multi-User Support	○	●	●	●	●	
Platforms Supported: Macintosh		●	●			
Platforms Supported: UNIX		●	●	●		
Platforms Supported: Windows	●	●	●		●	●
Prioritization Capability	●	●	●	●	○	●
Requirements Definition, Decomposition, and Allocation	●	●	●	●	●	●
Requirements History	●	●	●	○	●	●
Requirements Sensitivity Analysis	○	●	●	○	○	
Requirements Traceability	●	●	●	●	●	●
Reuse	●	●	●	○	●	●
Risk Management	○	○	○	○		
Standard Document/Query Generation	●	●	●	●	●	○
System Architecture Definition	●	●	●	●	●	●
Tool User Documentation /Training	●	●	●	●	●	●
User Interface	●	●	●	●	●	●
Vendor Support	●	●	●	●	●	○

Level of Support: ● = Strong, ● = Medium, ○ = Weak, Blank = None

Another trend observed is the demand for these types of tools to interface with other tools such as Microsoft Office, other analysis tools, etc. Vendors are responding to this demand by building Object Linking and Embedding (OLE), Open Data Base Connectivity (ODBC), and import/export capabilities into their products. Many of these tools also offer Application Programming Interfaces (APIs) which, in some cases, give the users broad capabilities to customize and tailor their tools.

It must be mentioned that the ability of a tool to operate in a heterogeneous environment is fast becoming a prerequisite with users. In fact, Microsoft Windows NT is becoming the server of choice, joining Novell and UNIX as a leader in network management. As long as users have the ability to choose between these operating systems, the need for platform-independent applications will continue.

3.1.5 Recommendations for Future Development

Considering the findings of the interviews, it is clear that program managers need requirements management tools. From the market assessment, it appears that several tools are viable candidates. The current assessment of requirements management tools revealed the following fundamental shortfalls in today's applications:

- World-Wide Web (Internet) enabled capabilities are not sufficiently rich.
- Security issues at all levels, including access and encryption, have not been adequately addressed.
- Risk management capabilities in these tools are virtually nonexistent.
- Interfaces to other tools are lacking.

Some of these issues, such as Web-enabled capabilities and security, are being addressed by software vendors. Any future enhancements and deployment of these tools should address these shortfalls.

The following steps outline an approach to providing a tool for use in requirements management.

1. Select a program for which to choose and deploy a tool. The obvious choice is one of the S&T IPPD pilot programs.
2. Choose one of the candidate tools that provides the core features as described in paragraph 3.1.2.
3. Modify the tool. Modification falls into two categories—modifications for the unique features that the pilot program needs and modifications to address the shortfalls of current tools as described above. Close interaction with the program manager and the IPT will be required to ensure that all needs are met. (Perhaps meetings using a group consensus tool would be in order to facilitate this interaction.)

4. Customize the tool to encompass the requirements and test documents (e.g., MNS and ORD) that the program requires.
5. Develop a test plan. Deploy the tool for testing over an appropriate time period.
6. Use lessons-learned and user feedback to improve the deployments to the rest of the pilot programs and, ultimately, the entire S&T community.

In terms of interfaces to other tools, it is recommended that an interface be built between the requirements-management tool and a group-consensus tool. This interface should allow two-way data exchange so that requirements can be exported to the group consensus tool for analysis and imported back into the requirements tool after completion. It must be noted that such an interface has been prototyped by AL/HRGA on the RAPID-WS research program. (The interface was built between RAPID-WS and GroupSystems.) This work should be leveraged for any future development efforts on S&T IPPD Tools and Methods.

Given the mature nature of the market for requirements tools and the work already accomplished on the RAPID-WS program, the amount of time needed to customize and deploy this kind of tool should be minimal. Specifically, most of the features and capabilities wanted in this kind of tool are already provided by several of the tools as shown in table 4. Thus, the recommended timing and level of effort for deploying requirements tools are as follows:

	<u>FY97</u>	<u>FY98</u>	<u>FY99</u>	<u>FY00</u>	<u>FY01</u>
Person-Hours	3000	5000	6000	2000	TBD
Deliverables	Customized tool deployed for one pilot program	Customized tool deployed for three more pilot programs	Customized tool deployed for remaining pilot programs	Customization and Deployment Plan for S&T community	Customization and deployment to entire S&T community

3.2 (Value Judgment via) Group Consensus

Following the established interview protocol, a group consensus tool presentation was given as an introduction to this tool area. This served as a high-level introduction to how this category of tool could be used within the context of the S&T IPPD process model, the capabilities of this type of tool, the general categories of this type of tool (e.g., collaboration, communication), and trends in product/tool development.

General comments on the introduction to group-consensus tools showed that this kind of tool would be valuable in achieving consensus for various pilot projects, especially given the variety of experts that would participate in the process. Most participants agreed that consensus is a powerful tool in that it builds on peoples' strengths, not weaknesses.

The remainder of this section presents the results of the interview sessions and the tools identified as candidates to provide group-consensus capabilities. The tools are then evaluated based on the needs identified by the users during the interviews. Also included are a discussion

on market trends related to group-consensus tools and recommendations for future development in this tool area.

3.2.1 Interview Results

As was the case for a requirements-management tool; the majority of interviewees agreed that a group consensus tool would be of great help in managing their programs. The program manager frequently faces the difficult task of reaching consensus for projects in the 6.3 technology arena. The deployment of an automated tool could ease the collaborative process, facilitate communication flow, and enable IPTs to agree on project terms, requirements, design, etc.

A set of "warm-up" questions was developed to stimulate the participants' thinking about group consensus tools. As was the case for requirements-management tools, this set of questions evolved based on participant feedback and the research team's review of the answers elicited. The final set of questions and representative responses are summarized below.

What tools and methods do you use to reach consensus and how do you employ them?

- Besides face-to-face discussion, we use only the telephone and electromail.
- IPTs are developed before contract award. They employ meetings, fax, mail, and e-mail for coordination.
- I use brainstorming, affinity techniques, nominal group techniques, inter-relationship diagram analysis, and prioritization techniques.
- Usually the strongest personalities within the IPT carry the day.
- We use all types of tools: utility analysis, multiple criteria/options, weightings, and pairwise comparison.
- Consensus occurs ad hoc over several years - during which the project refines its scope and definition.
- These tools seem to be a substitute for a program manager who doesn't use some sort of internal decision process, or know the participants in the process. They, in essence, dump all that responsibility on the group. In most applications, this could easily become a crutch and mask more serious experience or ability problems within management.
- They cannot replace the program manager. Regardless of the tools, ultimately someone must make the decisions. They are tools only to help the program manager. Sometimes a program manager may have a preconceived solution and go with it despite the team.
- We use no automated tools to reach consensus.

What are the benefits and/or shortcomings of using group-consensus tools to support both distributed and co-located IPTs?

- Consensus gives assurance that a big mistake isn't being made or an opportunity, lost.
- Consensus allows your stakeholders more voice in the process and provides an active vehicle for commitment.
- Consensus tools that provide for distributed collaboration are fast, but the U.S. Mail system works -- it's just slower. Also Federal Express or its clones work well. I have used all.
- A "Bunch Of Guys Sitting Around Talking" (BOGSAT) is used too much in AF planning.
- This could be an effective way of coordinating IPT direction.
- Shortcoming: Hidden agendas and not hearing answers/opinions prior to distributing votes is a concern. Benefit: Hidden way of allowing for group empowerment and relying on experts.
- The benefit is a coordinated initial requirement. Shortcomings are not in the tools themselves, but in their application (i.e., are all stakeholders participants in negotiations?).

Did the overview enable you to evaluate the requirements for group consensus tools to support the S&T IPPD process?

- It is obvious that such tools would be beneficial, but as far as understanding the key features that would be required to implement successful tools, no. Maybe we went through that part too quickly.
- I think this part was covered quickly. If substantially more time was spent on every survey portion like this one, this interview would last more than two days. Nevertheless, more time would have to be spent understanding the IPPD process and the group-consensus scenario, and in weighing available capabilities, for us to understand our requirements for group-consensus tools.

- It would have been more productive if a discussion had followed the briefing, or taken place during the briefing.
- Not really. Unlike the QFD scenario, there were no examples. I only have a notion of what some tools are like and how they would compare with one another -- advantages and disadvantages -- when applied to different projects.
- The overview was a good introduction to possible tools that are available, and to the capabilities they could bring to the decision-making process.
- Yes. It was a good introduction. Of course, it did not recommend a specific tool for our use.

What key elements of group consensus have we missed?

- Conflict resolution -- identifying conflicts, their solutions when possible, and impasses that must be addressed in the future.
- The human element needs to be addressed in more detail: how to control outspoken participants, identify the true experts versus the charlatans and snake oil salesmen, keep hidden agendas from derailing the process, etc.

From these participant comments, the following general observations can be made:

1. The methods that program managers now use to reach group consensus range from purely ad hoc procedures to Total Quality Management (TQM) techniques.
2. Reaching consensus is an ongoing activity throughout a project's existence.
3. There is concern that these types of tools may usurp the responsibilities of program managers.
4. Automated tools are not presently used to reach consensus.
5. The benefits of consensus tools, as well as some shortcomings, were recognized.

Bottom Line: These comments point to the need for a tool to help IPTs reach consensus on various issues. Although in many cases sound techniques are being used, in many more, BOGSAT is still practiced. The remarks also stress the importance of proper utilization of such a tool. Specifically, the tool can never replace the program manager, with whom the ultimate responsibility of a program rests. Such tools, however, can assist program managers in making and justifying better decisions.

The information gathered during this question-and-answer session set the stage for the next step in the interview process -- building a list of tool needs.

3.2.2 User Needs for Group Consensus Tools

As for the requirements-management tool area, the participants for this tool area were provided a pre-established list of features for their comment and refinement. Each session arrived at a fairly consistent list of approximately 20 consensus tool functional features. The predefined list of features and capabilities for a group-consensus tool was:

- 1. Easy to Use:** The tool's interface should be user-friendly. A GUI is preferable to command line approach. The tool should be easy to install and maintain. The tool should have import/export capabilities to other tools such as word processors and spreadsheets.
- 2. Anytime, Anywhere:** The tool should be capable of handling collaboration activities without regard to the times they occur or the location of the participants. The anywhere condition promotes "virtual", real-time meetings. The anytime condition allows users to access data and information whenever they are able to do so, but not necessarily in real time.

- 3. Active Notification:** The tool should notify participants whenever new information has been entered into the session, allowing immediate review.
- 4. Anonymous User Input:** The tool should allow group members the option of entering their thoughts anonymously. Anonymous input promotes the sharing of more ideas. This feature is especially useful when brainstorming.
- 5. Brainstorming:** The tool should enable all participants to express their ideas and thoughts on the subject matter being explored. Additionally, the tool should allow further discussion and clarification. For example, the tool should give participants the ability to add annotations, comments, or questions about comments entered by other participants.
- 6. Voting:** The tool should provide a voting mechanism. Voting can be used to see if a group is in consensus on issues. For example, if the group has delineated the requirements for a project, the voting mechanism could be used to prioritize ("rank and stack") the requirements. If the variance is large on some of the requirements, the group can revisit those issues to attempt resolution.
- 7. Report/Document Generation:** The tool should provide the capability to capture the entire electronic group-consensus session and then export the information to other tools (e.g., a word processor). By using the other features in this list, teams could use this type of tool to outline reports/studies, agree on content, assign responsibilities to team members, etc.
- 8. Structured Decision Analysis:** The ability to reach consensus on subjective and objective issues is vital to an IPT. A consensus tool should provide the capability to use structured decision analysis techniques, either as part of the tool or as an add-on. For example, the tool should allow the IPT to list, categorize, and prioritize issues/topics. Further, the tool should allow the IPT to use techniques such as the Analytic Hierarchy Process (AHP) or value engineering methodologies to reach consensus on these issues/topics.
- 9. Facilitator/Moderator Functionality:** The key to successful group-consensus meetings is facilitation. The tool should provide the facilitator with centralized control of the activities in which the participants engage.
- 10. Categorizer:** As mentioned in structured decision analysis, the tool should provide the capability to categorize issues and topics. For example, during a brainstorming session, the group may list 100 requirements for a new aircraft. It would probably be useful to categorize the requirements in terms of the major aircraft subsystems that address them – e.g., airframe, avionics, and propulsion.
- 11. Prioritizer:** The tool should provide the capability to prioritize information. For example, after an IPT has listed and categorized requirements for a new aircraft, the team may want to prioritize the requirements in terms of "must have" or "nice to have."
- 12. Multimedia Input:** The capability to incorporate all types of data (audio, video, text, graphics) is desirable. Furthermore, the capability to conduct "anywhere" meetings through audio and video capabilities is desirable. Market trends indicate these capabilities are being developed and should be commonplace within five years.

13. Whiteboard: The tools should be capable of providing interactive, real-time information sharing via a whiteboard facility. This capability is especially useful when conducting “anywhere” meetings.

14. Concept Visualization Techniques: The tool should provide the capability to visually demonstrate a concept, process, or product using rapid prototyping, simulations, or quick-and-dirty software demonstrations.

15. History: Group interaction should be threaded to track ideas or comments through ongoing communications. One should be able to see the original comment and all appropriate responses in one seamless area, without, for example, needing to open seven messages to get to an idea.

The participants were given the opportunity to comment on each of the above listed features and capabilities. They were also allowed to add or delete features and capabilities. Each interview arrived at a list of 15 to 20 features that the selected tool should have within its functional capacity. When the participants had finished editing the list, a vote was taken to determine which features were most important. The voting results for all five interviews are shown in Table 5. As with our list of features for the requirements-management tools; only the top 12 choices from each interview are shown as major features. Desired features are lined up across the table so that it is easy to see the degree of consensus.

The voting results shown in table 5 reveal that there is a core set of features upon which most of the participants agree. For the purposes of this analysis, a feature was considered as a core feature if it was ranked as a major feature (in the top 12) at least three times. Given this definition, the core features identified for a group-consensus tool are:

1. Action Item Tracking,
2. Active Notification,
3. Anytime, Anywhere,
4. Brainstorming,
5. Concept Visualization Techniques,
6. Easy to Use,
7. Facilitator/Moderator Functionality,
8. Prioritizer,
9. Report/Document Generation,
10. Structured Decision Analysis, and
11. Voting.

As was the case for requirements-management tools, the results show that some features were important to only one of the participant groups. This again supports the research team’s belief that every program will have different needs based its level of maturity and on the type of research involved.

Table 5. Major Features Desired for Group Consensus Tools

Interview #1 5 - 6 June 1996 Wright Laboratory	Interview #2 19 - 20 June 1996 Wright Laboratory	Interview #3 14 - 15 August 1996 Armstrong Laboratory	Interview #4 18 - 19 September 1996 Phillips Laboratory	Interview #5 16 - 17 October 1996 Rome Laboratory
Active Notification	Action Item Tracking	Action Item Tracking	Action Item Tracking	Active Notification
	Active Notification	Active Notification	Active Notification	Anonymous User Input
Anytime, Anywhere	Anytime, Anywhere	Anytime, Anywhere	Anytime, Anywhere	Anytime, Anywhere
	Brainstorming	Brainstorming	Brainstorming	Brainstorming
			Calendar/Scheduling Tool	Calendar/Scheduling Tool
Categorizer		Categorizer		
	Concept Visualization Techniques		Concept Visualization Techniques	Concept Visualization Techniques
Cross-Platform				
Cost				
Easy to Use	Easy to Use	Easy to Use	Easy to Use	Easy to Use
Facilitator/Moderator Functionality	Facilitator/Moderator Functionality	Facilitator/Moderator Functionality	Facilitator/Moderator Functionality	Facilitator/Moderator Functionality
Import/Export				
Prioritizer	Prioritizer	Prioritizer		Prioritizer
Report/Document Generation	Report/Document Generation	Report/Document Generation	Report/Document Generation	Report/Document Generation
Sensitivity Analysis				
	Structured Decision Analysis	Structured Decision Analysis	Structured Decision Analysis	
	Voting	Voting	Voting	Voting
	Whiteboard			Whiteboard

3.2.3 Market Assessment for Group-Consensus Tools

The following paragraphs summarize of the market assessment for group-consensus tools. First, the major features of interest are reviewed. Then, a summary is given of the tools available and how each tool provides the major features of interest. Next, a discussion of market trends is presented. Finally, recommendations are made for future enhancements of group-consensus tools.

3.2.3.1 Major Features of Interest

The major features of interest were ranked in the top 12 in at least one interview session. These features became the focus of interest in the market assessment. They are:

1. Action Item Tracking,
2. Active Notification,
3. Anonymous User Input,
4. Anytime, Anywhere,
5. Brainstorming,
6. Calendar or Scheduling Tool,
7. Categorizer,
8. Concept Visualization Techniques,
9. Easy to Use,
10. Facilitator/Moderator Functionality,
11. History,
12. Import/Export,
13. Platforms Supported: Macintosh,
14. Platforms Supported: UNIX,
15. Platforms Supported: Windows,
16. Prioritizer,
17. Report/Document Generation,
18. Sensitivity Analysis,
19. Structured Decision Analysis,
20. Voting, and
21. Whiteboard.

3.2.3.2 Group-Consensus Tool Candidates

Groupware, as a concept, has been around for a long time. Its current definition is: "Groupware is not only the forms or processes we use to shape our interactions, but it is the capacity to create, shape, and change these forms and processes as appropriate." Groupware did not exist as an accepted software category until Lotus Notes was first released in 1989.

Because the definition of groupware is so broad, products that fall into this include:

- Electronic Mail (e-mail): This category allows the most basic type of group interaction -- messaging -- and generally includes the ability to attach files.
- Workgroup-Enabled Applications: These types of applications offer built-in file-sharing features.
- Scheduling: These tools allow workgroup members interactive access to information about meetings and events. Some tools include their own e-mail capabilities while others are meant to work in conjunction with existing e-mail systems.
- Conferencing: These relatively new applications allow users in geographically separate locations to share information on-screen in real-time (to support "anywhere" meetings).

An integral part of group-consensus functionality is conferencing. Conferencing products, thus, became the focus of this segment of our research.

Our search for COTS tools that offer conferencing functionality supported the notion that the conferencing-software market is expanding rapidly. Table 6 overviews the potential candidates for group consensus tools. Once identified, these tools were evaluated against the major features listed in paragraph 3.2.3.1.

Table 6. Group Consensus Tool Candidates

Company	Product	Description	Cost	Contact
Ventana Corporation	GroupSystems	PC Based. Collaboration, anytime, anywhere	\$895 user	1430 E. Ft. Lowell Rd Suite 301 Tucson, AZ 85719 (800)368-8319
TRAX Softworks Inc.	TeamTalk 2.0	PC Based. Collaboration, anytime, anywhere	\$395 5 users	5840 Uplander Way Culver City, CA 90230-6620 (800)367-8729
Enterprise Solutions, Inc.	MeetingWorks for Windows	PC Based. Collaboration, anytime, anywhere	Free	60 Union St. Suite 3232 Seattle, WA 98101 (206)467-1234

Table 6. (Concluded)

Company	Product	Description	Cost	Contact
Expert Choice Inc.	Team Expert Choice for Windows	Decision Support, AHP	\$14,295 Software and Hardware	5001 Baum Blvd. Suite 650 Pittsburgh, PA 15213 (412)682-3844
TeamWARE	TeamWARE	Collaboration, anytime, anywhere	\$2,495, 10 seats	800 Central Expressway Santa Clara, CA 95052 (408)982-9143
Crosswise Corporation	FacetoFace	Collaboration, anytime, anywhere	\$59	105 Locust St. Santa Cruz, CA 95060
Data Fellows Ltd.	Vineyard	Collaboration, anytime, anywhere	\$295 ea. \$18,000 for 100 users	4000 Moorpark Ave. Suite 207 San Jose, CA 95117 (408)244-9090
White Pine	CU-SeeMe	Collaboration, anytime, anywhere	\$295	542 Amherst St. Nashua, NH 03063 (603)886-9050
Collabra Software Inc.	Collabra Share 1.01	Collaboration, anytime, anywhere	\$995 server, \$99 user	1091 N. Shoreline Mountain View, CA 94043 (800)474-7427
Attachmate	OpenMind 1.0	Collaboration, anytime, anywhere	\$995 server, \$295 user	8230 Montgomery Rd. Cincinnati, OH 45236 (513)794-8290
Mesa Group, Inc.	Conference+ 1.1	Collaboration, anytime, anywhere	\$75	29 Crafts St. Newton, MA 02160 (617)964-7400
Avantos Performance	DecideRight 1.0 for Windows	Decision Support	\$149	5900 Hollis St. Emeryville, CA 94608

3.2.3.3 Group-Consensus Tool Evaluations

The same tool evaluation approach was used for group-consensus tools as was used for requirements-management tools. With the needs for a group-consensus tool delineated and the potential COTS tool candidates identified, the two were compared. Again, no recommendation was made regarding specific tools a program manager should use.

The results of the tool evaluations are presented in table 7. As with the requirements-management tools, each candidate group-consensus tool was evaluated against the features identified in the interviews. Only the top twelve features from each interview were evaluated. The table should be interpreted as before:

1. ● indicates the tool offers strong support for the feature,
2. ▴ indicates the tool offers medium support for the feature,
3. ○ indicates the tool offers only limited or weak support for the feature, and
4. A blank cell indicates the tool offers no support for the feature.

As with the requirements-management-tool evaluations, program managers should use the results of the group-consensus evaluations to choose tools that appear to provide the features they need, then evaluate the tools for themselves.

3.2.4 Market Trends in Group Consensus Tools

The future for groupware, particularly conferencing/consensus products, appears to be promising. As the trend towards workgroups and the team model increases, more applications such as word processors and spreadsheets will integrate workgroup functionality. More focused tools, such as the Analytic Hierarchy Process (AHP) for decision analysis, are also gaining popularity.

Ovum, Ltd. attributes 19 percent of the present groupware market to stand-alone e-mail systems and 33 percent to workflow systems. *Ovum* forecasts that, as e-mail functionality is integrated with other technologies, stand-alone e-mail will account for only 10 percent of the market in 1998.

The scheduling and conferencing groupware market segments are expanding rapidly, as new vendors add products with increasing frequency and users buy them to fill their needs. *WorkGroup Technologies* expects scheduling-tool revenue to grow by 103 percent in 1997, while conferencing-tool revenue will increase by 171 percent during the same period.

The Internet will also impact the groupware market. The ability to conference over the World-Wide Web ("Web") holds great promise. In fact, some of the tools identified in this research are already Web-enabled. Although the Web is exploding rapidly, it has not yet become the "information superhighway" envisioned. As it grows and matures, it is likely to have great impact on workgroup tools. For this reason, it is important to stay informed about the advances in Web technology and its impact on group-consensus tools. This is not to say that tools that are not Web-enabled cannot support group consensus. However, it may be the case that Web-enabled products can support group consensus in more ways.

Table 7. Group Consensus Tool Evaluation

FEATURE EVALUATED	GroupSystems	TeamTalk 2.0	MeetingWorks	Team Expert Choice	TeamWARE	FacetoFace
Action Item Tracking		●	●			
Active Notification	●	●	●			
Anonymous User Input	●	●	●	●		
Anytime, Anywhere	●	●	●	●		●
Brainstorming	●	○	●	●	●	
Calendar or Scheduling Tool		●			●	
Categorizer	●	●	●	●	●	
Concept Visualization Techniques						
Easy to Use	●	●	●	●	●	●
Facilitator/Moderator Functionality	●	○	●	●		
History	●	●	●			
Import/Export						
Platforms Supported: Macintosh					●	
Platforms Supported: UNIX					●	
Platforms Supported: Windows	●	●	●	●	●	●
Prioritizer	●		●	●	●	
Report/Document Generation	●	○	●	●	●	
Sensitivity Analysis						
Structured Decision Analysis	●		●	●		
Voting	●		●	●		
Whiteboard	●		●			

Level of Support: ● = Strong, ● = Medium, ○ = Weak, Blank = None

Table 7. (Concluded)

FEATURE EVALUATED	Vineyard	CU-SeeMe	Collabra Share	OpenMind 1.0	Conference+ 1.1	DecideRight 1.0
Action Item Tracking	●					
Active Notification		►	►	●	○	
Anonymous User Input	●			●	●	
Anytime, Anywhere	●	●	●	●	●	
Brainstorming	●	►	○	●		
Calendar or Scheduling Tool	●		►		►	
Categorizer	●				►	●
Concept Visualization Techniques						
Easy to Use	●	●	●	●	●	●
Facilitator/Moderator	●	●				
Functionality						
History	►		●	►	►	
Import/Export						
Platforms Supported: Macintosh		●	●	●		
Platforms Supported: UNIX				●		
Platforms Supported: Windows	●	●	●	●	●	●
Prioritizer		►				●
Report/Document Generation						●
Sensitivity Analysis						
Structured Decision Analysis		►				●
Voting	●					
Whiteboard		●				

Level of Support: ● = Strong, ► = Medium, ○ = Weak, Blank = None

3.2.5 Recommendations for Future Development

Considering the findings of the interviews, it is clear that program managers need group-consensus tools. From the market assessment, it appears that several tools are viable candidates. The current assessment of group-consensus tools revealed the following fundamental shortfalls in today's applications:

- Web (Internet) enabled capabilities are not sufficiently rich.
- Security issues at all levels, including access and encryption, have not been adequately addressed.
- Import/export capabilities are not supported.
- Sensitivity analysis is not provided.
- Interfaces to other tools are lacking.

Several of the tools shown in Table 7 provide most of the features that users need. Recommendations for future development in this tool area parallel those made for the requirements-management tool area. Because these areas are closely interrelated, the same pilot program should be chosen. A group-consensus tool should be chosen that provides those core features identified in paragraph 3.2.2. Because group-consensus tools and requirements-management tools have similar shortcomings, many of the modifications desired for each will also be similar. It is recommended, however, that a tool be chosen that is Web-enabled, to enhance distributed IPT collaboration. The same test and deployment procedures should be carried out as outlined for the requirements-management tool. Again, it is emphasized that the work accomplished on the RAPID-WS program must be leveraged in any effort to customize these tools.

The schedule and level of effort appropriate for adopting group-consensus tools should be similar to those appropriate for adopting requirements-management tools.

	<u>FY97</u>	<u>FY98</u>	<u>FY99</u>	<u>FY00</u>	<u>FY01</u>
Person-Hours	2000	4000	6000	1000	TBD
Deliverables	Customized tool deployed for one pilot program	Customized tool deployed for three pilot programs	Customized tool deployed for remaining pilot programs	Customization and Deployment Plan for S&T community	Customization and deployment to entire S&T community

3.3 (Program Management) Workflow

"Workflow" is a relatively new term and, as such, is generally not well understood. Articles on workflow paint sometimes conflicting pictures and often mingle terms such as "workflow" and "groupware". As figure 1 suggests, workflow and groupware play related but play different roles in the business process.

“Workflow,” first, can refer to a collection of tasks or activities in a business process. Second, it can refer to the execution of those tasks and activities. Third, it can refer to the software used to manage, measure, track, coordinate, and revise those tasks and activities. In the context of this effort, “workflow” was used to represent a software environment or infrastructure that supports multiple workers and applications throughout a business process.

What is the difference between groupware and workflow? “Groupware” represents the underlying infrastructure upon which workflow and other applications (e.g. group consensus and decision support) rely. It can be thought of as a *data and communications infrastructure*, while workflow, which is a layer “above” groupware, can be thought of as *the business process control infrastructure*. Applications such as group-consensus tools can be implemented in groupware systems, while they may or may not interact with a workflow system.

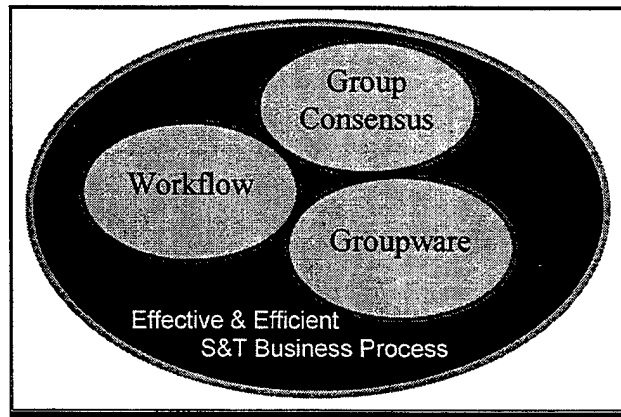


Figure 1. Relationship Between Groupware, Workflow, and Group Consensus

Note that we speak here in terms of groupware and workflow *systems*. The workflow systems to which we refer are implemented in software, due to the complexity of today’s information-intensive environments in which such tools are being employed. Historically, the “flow of work” has not been managed in any area other than manufacturing. In paper-based organizations, everyone learned by an informal apprenticeship how things were done, what went where, and how long things took. Organizations depended on secretaries. (A few still do, although even in those cases, the role of the secretary is changing, and the ratio of secretaries to managers has decreased dramatically.) The secretaries had the broadest view of the flow of work. They knew the time required by various tasks and where the bottlenecks existed.

Modern workflow is gradually replacing analogous secretarial functions. It enables the inclusion of increased functionality in the business process. It does not replace human review and management of work, but it substantially augments them. Workflow does not necessarily mean that business processes are managed or performed with fewer people. It does mean that the processes, which are now more flexible and responsive to changes in the environment, are tractable; prior to the advent of workflow, they were not. Workflow is replacing certain older functionality (e.g., work tracking and some other secretarial functions), integrating common functionality (e.g., scheduling), enabling more complex functionality (e.g., task negotiation and process analysis), providing for the management of a vast amount of information and control (decision history, progress reporting, distributed management, et al.), and, ultimately, supporting business process and systems engineering with improved change-management.

As indicated earlier, it was necessary to provide the interviewees with considerable background information and an example scenario for this tool area. The scenario walked them through a

“day in the life” of a 6.3 program manager, illustrating how a workflow system could ease many critical tasks. Key workflow tasks included:

- Project sharing and allocation among personnel and resources;
- Event management to enhance a proactive capability to anticipate pending actions and track actions in progress;
- Notification, request, and negotiation of tasking, so that the right resources are applied to various tasks, and there is consolidated notification to the program manager concerning pending and/or overdue actions;
- Integration of tasks and applications, so that the right applications are applied to given tasks;
- Corporate “memory” via the active capture, organization and archival of the process activities and information;
- Process management through enforcement of the business rules; and
- Continuous process improvement by enabling the effective capture of process innovations and the measurement of process effectiveness.

The objective of the interviews was to introduce participants to the AFMC S&T IPPD process and to collect from them the features or capabilities that these tools should possess in order to assist them in implementing the process. Following the briefings and scenario demonstration/simulation, participants were asked to respond to a set of warm-up questions. After the warm-up questions, they were asked to review and help build a list of functional needs that workflow tools should support. Finally, they were asked to rank those functions and features in order of importance from their own perspective as S&T program managers.

3.3.1 Interview Results

As expected, participants struggled more with workflow (and value analysis) than they did with the requirements-management or group-consensus portions of the interviews. The reason for their difficulty was that the implementation of workflow tools is not a familiar activity, and indeed, the workflow market is still defining itself. People do not yet employ workflow tools the way they use requirements-management and even group-consensus tools. In part because it is more difficult to understand, workflow was viewed as a potentially critical, but longer term, implementation issue. The scenario demonstrated how workflow could help in the conduct and management of a complex project. Most participants indicated they would like to have access to such a system. However, there was concern, expressed by both government and contractor personnel, about how to sufficiently populate a workflow system to make it really useful to a program manager.

The results of the warm-up questions are provided below. As noted earlier, these questions did evolve somewhat during the course of the interviews. In particular, questions with respect to the effectiveness of the scenario demonstrations were added for the third through fifth interviews.

How might a workflow tool enable you to track long-term success (i.e., technology transfer)?

- It would provide a historical database: who contributed what, when, and where; what problems occurred and how they were corrected; shortfalls; pitfalls; applications; etc.
- I believe this tool would be helpful but not to the same level as some of your earlier tools. I like the idea of this tool since it would allow me better visibility into how the different work packages are progressing, if/how I need to take action, and how my project may impact other projects.
- It would help to keep all the project information intact. Right now I'm sure there are some efforts that have gone through several years of work with several different program managers; a lot of the documents developed and decisions made are nowhere to be found. This tool could enable us to electronically capture management history and help us in the present.
- It would facilitate communication between IPT members to show them how user requirements are being translated into a lab prototype and how that is being brought to EMD. It would also help ensure that little gets lost in the translation from one project phase to another.
- This question is a little disingenuous. It's pretty obvious that tools like this could keep things on track, alert the manager to problems with enough lead time to take corrective action, etc. There'd be no surprises without an outright effort to deceive.
- A workflow tool would allow each member of a team to impact decisions, solutions, etc. Thus, the process and thinking that went into the decision process would be maintained and it would be easier to answer why or why not you considered a particular solution or technology. In addition, it would provide the ability to look back at other alternatives and pick up parts of them that may help solve current problems.
- As with all such systems, quality consolidation of the information and good indexing for retrieval will drive the overall usefulness of the archived information.

How might workflow tools impact the execution of the S&T IPPD process?

- I don't see how the S&T IPPD process can be implemented effectively without workflow tools that work.
- These tools should help by integrating management activities into one environment.
- I agree with the above statement, and would add that tools of this sort could help management activities in general, not just IPPD. They would have great value even if there were no IPPD concept. What I saw covered every aspect (that I can think of so far) of oversight, coordination, etc., that managers need to do.

- Workflow tools should allow the process of technology development to be smoother and more efficient. They could help to avoid the problems of schedule conflicts when everyone can not get together. People could work at their own pace as long as they met the overall schedule. And, if a member of a group were only interested in impacting one or two parts of a project, he could look at only them. He would not have to waste time sitting through meetings when the discussions are on other subjects.
- They could enable the tracking of schedule deviations, identify technology challenges not anticipated during original planning, help resolve issues between IPT members, and provide a simplified means of information reporting.
- They are critical for real communication between distributed teams and for tracking whose belly button needs pushing. Metrics of both defined and ad-hoc processes are required for the management (and I think all) levels.
- Government - S&T, Industry - S&T, and Industry EMD would all be singing from the same sheet of music. This means two things: 1) S&T would be less intangible, 2) technology transition would be more straightforward (e.g., you could plug in another contractor at any time you wished).

Could a workflow tool help build advocacy or "buy in"? Please Explain.

- This is a tougher question than the others. I'm not sure how it would help buy-in at the start. I guess as things went along and some of the risky things needed to get solved, the openness of the tool would allow everyone the same understanding of the problems, a voice in fixing them, and a sense of ownership due to having helped.
- Would management, the customer, and the program manager all have unrestricted access to the program manager's files? I'm not sure that kind of exposure is good for a project. It would not give the program manager time to work through problems on his/her own, and would invite micromanagement. The program manager would lose control.
- A workflow tool would support buy-in by giving all of the team members access to all of the information available on the program. Information is the key to survival.
- A workflow tool would allow all parties to actively participate in all issues at any time. It would allow immediate responses to questions from all parties involved. You could assume this would promote advocacy. However, the program manager would then be responsible for assuring all parties report when required or desired.
- "Buy in" must extend to laboratory-management and contractor willingness to support such a tool, and to participate (e.g., update reports) as required. I think that starting simple to demonstrate the benefits of the workflow tool would help build advocacy within the laboratory, laboratory management, and even other contractors.

- Two ways: First, it would keep users plugged in to the program throughout its life, which helps guarantee some technical pull from the users at the worker bee level. It also would help when pitching to decision makers (MAJCOMs, SPOs, etc.); the program manager could show a historical perspective of the program as part of a familiarization briefing.
- It could, by providing a medium through which multi-party dialogue (from users, investors, sellers, buyers, etc.) could occur, driving toward the development by each party of a personal picture of what's in it for them.

Did the demonstration enable you to understand workflow tools and how they might support the S&T IPPD process?

- I think the demonstration enabled me to understand the use of workflow tools. I think they would be used by contractors in the execution of ISCP projects. But, I still find it hard to see how they could be implemented within the laboratory.
- I suspect that every scientist would want every feature that has been described here. I also suspect that if anyone bothered to survey the actual use of the features among scientists five years down the road, they'd find that very few of these features were actually used. They are all "nice to have", but I don't see anyone jumping up and down saying that he just has to get them right now.
- It made me realize that, as with all management tools, the user must define what his requirements truly are and understand the options available before he can make a viable tool choice.
- Yes, the demonstration allowed me to understand workflow's importance to the process. However, the demonstration also scared me. There are many tools about which I have no working knowledge. There will be no delivered tool that performs all the tasks as described. Once the technical support for the tool is gone, who is responsible? Me. I would probably require a person to continue this support, freeing me to handle technical and program issues.

What key elements of workflow have we missed?

- There probably are some, but I'd need to work with a tool to find them by realizing that something wasn't supported. It looks pretty thorough conceptually.
- I would have liked to have seen how the financial functions could be interfaced into the workflow.
- One word: Cost! I know cost is based on level of implementation, but you should give team members some idea of the cost for these tools. S&T projects are usually financially constrained.

Based on these comments, the following general observations can be made:

1. A key perceived benefit of workflow is the ability to track project/corporate history and provide an audit trail of the decision process.
2. The capture of project history is required for the ability to manage long-term programs in the face of personnel turnover, and for the transition from one project phase to another.
3. An important function of workflow is to facilitate closer linkage and increased involvement (and, thus, ownership) of each IPT member.
4. There is no consensus yet on the importance of workflow in S&T. Some individuals feel it is essential while others believe it is a longer term issue for which the payoff might be somewhat dubious today.
5. Program managers liked the idea that workflow could help with automatic notification and action tracking throughout a project, but they were concerned about a loss of control over the project should upper management be permitted to gain premature access to project activities. At issue was the notion of the *management processes to control access to workflow systems*.
6. The scenario demonstration proved to be an extremely important aid to helping the participants visualize how various tools, especially workflow, could support S&T project management. This fact became clear when comparing the quality of the feedback from the first two sessions, where there was no scenario, with that of the last three sessions, where the scenario was added.
7. The financial/cost issue was not sufficiently addressed in the scenario. Comments on cost involved four areas: the use of workflow to support cost and schedule tracking throughout a project, the integration of workflow with applications that support transition cost estimation during S&T, the cost of implementing workflow in fiscally constrained S&T projects, and the cost of sustaining workflow software in a manpower-constrained environment.

Bottom Line: Workflow is potentially very important to S&T, but its implementation is a longer term issue that depends on S&T budgets, the infrastructure to support it, and the perceived payoff. Fundamentally, ways must be found to implement workflow in S&T that take a risk-averse approach (e.g. incremental implementation). Implementation costs must be carefully controlled, and only those functions that are truly value-added and that would actually be used by program managers should be implemented.

3.3.2 User Needs for Workflow Tools

As noted above, the interviewees in the later sessions benefited from the work accomplished in the early sessions. The last three sets of interviewees were provided with a set of functional needs which they were asked to review and embellish. The workflow tool functional needs that were provided to the latter three interview groups were as follows:

1. **Ad hoc:** The tool should be capable of implementing variable or infrequently-used processes.
2. **Application Integration:** The tool should be able to use a variety of COTS applications together, seamlessly, to support an overall process.
3. **Audit Trail:** The tool should have the capability of maintaining an audit trail of work status and key decisions. Most projects span several years, during which personnel turnover and loss of corporate memory can cause problems. Capturing this information can alleviate some of these problems. Archiving and backing up the data are, therefore, necessary.
4. **Calendar Support:** The tool should support task and personnel scheduling, automatic notification of events, and schedule-conflict resolution. The tool should be network-enabled to support scheduling among distributed IPT members.
5. **CDRL (Contract Data Requirements List) Reduction:** The tool should be capable of interfacing with COTS software (word processing, presentations, graphics, and scheduling) in order to allow contractors to create weekly/monthly reports capturing the pertinent program information in any format. The tool should allow the generation and distribution of test reports, procedures, and plans, or any typical CDRL item in electronic form. Of course, there will always be items where a "hard copy" is required.
6. **Coordination:** The tool should facilitate setup and use of data and information. This capability includes the dispersion of data and information resulting from the execution of an assignment or application. The tool should provide collaboration on and synchronization of tasks and activities. When processes include the routing and coordination of documents, the tool should maintain the status, due dates, etc. for such documents.
7. **Customization to Particular Processes:** The tool should be customizable and tailorable either through a built-in development environment and/or APIs. This feature would allow greater flexibility in implementing workflow in the S&T IPPD Process.
8. **Document-Centered:** The tool should be capable of implementing workflow defined by processing-routed documents or work packages.
9. **Group/User-Centered:** The tool should be capable of implementing the workflow process of a general set of tasks to be performed by multiple users in a coordinated fashion.
10. **Large-Scale Standardization:** The tool must be standardized across a large organization such as Phillips Lab to allow program managers to acquire and turn over programs easily. Too much personalization of the tool will inhibit this turnover.
11. **Match Government File Systems:** Systems to electronically track records must agree with office systems already extant to track hard copies of documents. Otherwise, people would be stuck with two systems to learn and would use both poorly.
12. **Open Systems:** The tool should operate across platforms and operating environments.

13. Production Processes: The tool should have the capability to implement repetitive processes, following codified rules.

14. Progress Tracking: The tool should have the capability to track the progress of and measure the effectiveness of business processes. The tool should be capable of capturing process metrics for analysis.

15. Project Management: The tool should provide the capability to assign activities and work packages, including negotiation of task resources, objectives, and schedules. The tool should enable the manager to prioritize tasks and enable team members to react to priorities. The tool should prompt team members when activities need to be done or when a suspense is due. The tool should also feature management reporting.

16. Security/Limited Access: The tool should handle some security aspects of programs. If the project includes proprietary or classified aspects, it should be able to reference them. There should be a procedure by which a person can be approved or refused access to that data.

17. System Facilitator: First, someone with clout must be established to enforce use of the system. It cannot be optional. Second, the workflow tool should support task facilitation and business-rule enforcement.

18. Visualization: The tool should provide a graphical capability to define and test proposed processes.

The voting results shown in table 8 represent the core set of features agreed upon by the majority of participants in each of the interviews. For the purposes of this analysis, a “core” feature was ranked in the top twelve to fifteen features in at least two of the interviews. The core features identified for workflow tools were:

1. Application Integration,
2. Audit Trail,
3. Calendar Support,
4. Coordination,
5. Customizable,
6. Document-Centered,
7. Group/User-Centered,
8. Open Systems,
9. Production Processes,
10. Progress Tracking,
11. Project Management,
12. Security,
13. System Facilitator, and
14. Visualization.

Table 8. Major Features Desired for Workflow Tools

Interview # 1 5 - 6 June 1996 Wright Laboratory	Interview # 2 19 - 20 June 1996 Wright Laboratory	Interview # 3 14 - 15 August 1996 Armstrong Laboratory	Interview # 4 18 - 19 Sept 1996 Phillips Laboratory	Interview # 5 16 - 17 October 1996 Rome Laboratory
	Ad-Hoc			
Application Integration		Application Integration	Application Integration	Application Integration
Audit Trail	Audit Trail	Audit Trail	Audit Trail	Audit Trail
Calendar Support	Calendar Support			
Coordination	Coordination	Coordination	Coordination	Coordination
Customizable	Customizable	Customizable	Customizable	Customizable
Document-Centered	Document-Centered	Document-Centered	Document-Centered	Document-Centered
Group/User-Centered	Group/User-Centered	Group/User-Centered	Group/User-Centered	Group/User-Centered
			Large Scale Standardization	
Open Systems	Open Systems	Open Systems	Open Systems	Open Systems
	Production Processes	Production Processes		
Progress Tracking	Progress Tracking	Progress Tracking	Progress Tracking	Progress Tracking
Project Management	Project Management	Project Management	Project Management	Project Management
Security		Security	Security	Security
			System Facilitator	System Facilitator
Visualization	Visualization	Visualization		Visualization

3.3.3 Market Assessment for Workflow Tools

The market assessment for workflow was based on an evaluation of available workflow tools with respect to the functional needs listed in paragraph 3.3.2, as well as an assessment of a few key underlying technical requirements needed to address the user-defined functions. Only tools that addressed the following key functions were further assessed:

- Web enabled -- Capable of supporting workflow functions across a distributed environment,
- Industry-wide platform compatibility -- Compatible with Windows NT, and
- Commitment to support Common Object Oriented Request Broker Architecture (CORBA) standards for inter-application integration.

Over 130 workflow tools were screened in a preliminary review, but the more detailed assessment below is limited to the only three workflow tools that were Web enabled at the time of the review. Because of the importance of the Internet as an infrastructure to support platform-independent client-server applications, it is likely that many more workflow tools will become Web-enabled in the near future. A discussion of market trends in terms of industry initiatives follows the workflow tool summary, and this section of the report concludes with recommendations for future workflow tool selection and implementation.

3.3.3.1 Major Features of Interest

Table 8 reveals that some features were important to only one or two of the participating groups, reinforcing the notion that each program will have different needs based on the type of research and the maturity of the technology. The features in table 8 are listed alphabetically. The initial interview identified two issues -- ease of use and affordability -- that were considered important but are not listed here. Ease of use is a standard requirement for any tool to be effective. Affordability (in terms of the cost of tool purchase, deployment, and maintenance) is also essential. Desired features are lined up across the table so that it is easy to see the degree of consensus.

3.3.3.2 Workflow Tool Candidates

The market assessment for workflow tools began with an initial screening of over 130 tools which purport to support workflow. This large list was quickly culled to a handful of applications, three of which are Web-enabled. A key criterion was the ability of a workflow tool to support S&T business processes among geographically distributed members of an IPT. This portion of the task was somewhat attenuated due to increased emphasis on the tool interviews. The loss is small, however, because regardless of what is published in this report with respect to workflow, it will be out of date within six months. The market is changing rapidly, and there will be a major shakeout with a handful of clear market winners during the next two to three years.

In spite of the current relative immaturity of this market and the emerging nature of Web-enabled applications in general, we were able to find three Web-enabled workflow tools that appear to meet many of the user-identified needs. The tools identified as potential candidates for workflow are shown in table 9.

3.3.3.3 Workflow Tool Evaluations

The workflow tools identified in table 9 were evaluated against the major tool features/capabilities described above in paragraph 3.3.3.1. The results of this evaluation are presented in table 10. Each tool was evaluated against the desired features based on vendor claims and, where possible, hands-on testing. The key to the table is:

1. ● indicates the tool offers strong support for the feature or function.
2. ◐ indicates the tool offers medium support for the feature or function.
3. ○ indicates the tool offers only limited or weak support for the feature or function.
4. A blank cell indicates the tool offers no support for the feature or function.

Table 9. (Web Enabled) Workflow Tool Candidates

Company	Product	Description	Price	Contact
Action Technologies	Metro	PC Based, web-enabled Workflow System	\$4,995 Developer Tool (1 required) \$199 each additional Analyst version Client licenses: \$27.5k/ 200 user, 55k/500 user \$82,500, unlimited \$9,995 Metro 1.1 Developer Starter Kit (includes 30 users)	1301 Marina Village Pkwy, Suite 100 Alameda, CA 94501-1028 (800) WORKFLOW
Universal Energy Systems	Track It	PC Based, web-enabled Workflow System	\$18,000 KI SHELL Devel. Ver. \$1,200 Additional Runtime licenses (KI SHELL) \$800 per concurrent user	Dr. Jay Ramanathan - Dir. of Knowledge Integ. Center 5162 Blazer Pkwy, Dublin, OH 43017 (614) 792 - 9993
Lotus	Lotus Notes		\$681, Notes 4.0 for Server (1 required) \$407, Notes 4.0 Client (1 required) \$112, Notes 4.0 DT Client (1 per user) \$900, 10 License Pack \$1,760, 20 License Pack \$895, Starter Pack (includes 1 Server, 1 Client and 2 Desktop Clients)	55 Cambridge Pkwy Cambridge, MA 02142 (617) 577 - 8500
Quality Decision Management, Inc	Business Builder	(Requires Lotus Notes)	\$1895 per Server -- Requires Notes Release 4 and a Windows Client. Runs on all server & client platforms supported by Notes Release 4	200 Sutton Street, Suite 225 North Andover, MA 01845 (508) 688 - 8266

It is stressed that the tool evaluation was accomplished by reviewing vendor literature and third party reports. In some cases, demonstration copies of the tools were obtained and reviewed. In other cases, vendors demonstrated the tools. The reader is cautioned that the only way to verify software vendor claims is to actually employ the software in a demanding application. The resources on this preliminary analysis task were not sufficient to accomplish that level of test and evaluation. It is also stressed that in the area of workflow the marketplace is extremely dynamic. Workflow tool selection must involve the specifics of the intended application and the emerging developments in the workflow marketplace.

Table 10. Workflow Tool Evaluations

FEATURE EVALUATED	Action Tech.: Metro	UES: Track It	Lotus: Notes	QDM: Business Builder
Application Integration	■	■	■	■
Audit Trail				
Calendar Support			■	■
Coordination	●	■	○	○
Customizable	●	●	○	■
Document-Centered	●	●	○	○
Group/User Centered	■	■	○	○
Open Systems	●	■	●	●
Production Processes	●	●	○	■
Progress Tracking	●	■	○	○
Project Management	●	■	○	○
Security	■	■	●	●
System Facilitator	■	■		○
Visualization	■	●		○

3.3.4 Market Trends in Workflow Tools

As indicated above, the marketplace for workflow tools is extremely dynamic. The fundamental issue will be ease of implementation, which translates into development and support costs. Because workflow is by nature a complex endeavor, reducing the overhead associated with workflow applications will require the software to be more “intelligent.” The concept of “intelligent agents” is one of the most promising approaches to making workflow software more powerful, yet easier to use.

Within the next five years, the majority of workflow applications will be implemented in Internet or Internet environments. Microsoft’s next generation object-oriented operating system, currently named Cairo, will provide highly integrated Internet capabilities. The application suites and workflow tools that run on Cairo and other operating systems will automatically benefit from this integration so that the notion of being “Web enabled” will be essentially universal.

It is likely that within three to five years, a new breed of Internet development tools based on Java will emerge to provide a more robust capability for integrating numerous applications within a workflow context. A key to distributed computing will be the emergence of standards such as the Common Object Request Broker Architecture (CORBA). They will enable a new level of application integration and information via a common set of Application Program Interfaces (APIs). Many of the workflow functions listed above will ultimately be built into commercial operating systems or will be available as extensions to popular operating systems. Workflow systems, however, will always require tailoring to the specific business applications or environments in which they are deployed. The proliferation of workflow tools will, therefore, reinforce the current trend toward process-driven metrics and management.

3.3.5 Recommendations for Future Development

The current assessment of workflow tools revealed the following fundamental shortfalls in today's applications:

- Web (Internet) enabled capabilities are not sufficiently rich.
- Tools are immature and are often limited by the platforms they support.
- The tools are too difficult to use and require a major commitment to implement and support.
- Security issues at all levels, including access and encryption, have not been adequately addressed.
- Issues between government and contractor entities, as well as issues between contractors, remain to be resolved. They are particularly poignant in a workflow environment where intersections must be established between different business processes.
- Process models for the business side of the enterprise that are analogous to those for the product side of the enterprise do not generally exist. These models are required for effective workflow implementation.

Certain issues, such as Web enabled capabilities and product maturity, are being addressed by software vendors. Implementation issues are also being addressed by commercial tool vendors. Tools will become easier and more cost-effective to implement, and security capabilities are a design goal for most Web-enabled products today. However, the world of commercial software tools and vendors is not addressing the prime-supplier value-chain issues that require workflow to be employed across multiple organizations, including those of both government and industry, particularly in the context of defense research and acquisition.

Because commercial software vendors are investing heavily in the development of improved workflow tools, the Air Force should closely follow commercial developments in this area, and invest, instead, in workflow *applications* – the tailoring of commercial workflow tools to support defense-unique needs. Because workflow touches almost every aspect of a process, workflow

applications would likely be complex and expensive to implement. (This is less true of group-consensus applications because they can be targeted at specific problems and, hence, can be of more limited scope.) With respect to the S&T IPPD initiative, the extent the workflow applications provide return on the investment required for their implementation remains to be seen. We do not anticipate that workflow will play a significant role in FY97 S&T IPPD pilot programs. There are, however, applications for workflow that should be considered which may impact S&T programs in the future.

One of the most important defense needs is to address the problem of enterprise integration where the “enterprise” consists of one or more prime contractors and numerous suppliers (even multi-tier suppliers). This situation would be extremely rare for S&T but is common during acquisition. Commercial workflow solutions have not really addressed the issue of workflow across the extended enterprise described here. We, therefore, recommend two S&T efforts to explore the application of workflow to that environment. The first recommendation addresses the need for improved methods to model the enterprise processes that the workflow system would support. The second recommendation, building on the first, outlines an experiment in applying workflow to the enterprise processes in a defense context.

3.3.5.1 Recommendation 1: Heuristic Models for Process Representation (HMPR)

Background: Companies are developing sophisticated Process Capability Models (PCMs) which link their manufacturing process capabilities to design features. PCMs improve the design process by enabling products to be “manufactured in a computer” before being submitted to “real world” manufacturing. These PCMs are not manufacturing simulations, but represent a next-generation set of heuristic “design rules” with which designers interact in “real time” as they make critical design decisions. Companies are succeeding in building these heuristic representations of the manufacturing process at far less expense (and complexity) than is the case with more conventional modeling and simulation. The question is whether analogous PCMs could be built for the *business processes* that drive an organization. If so, they could dramatically improve our capability to understand and continuously improve those processes.

Relevance to Workflow: Workflow systems implement and help enforce business processes. Ultimately, a workflow system should support continuous process improvement. That kind of support is not possible, however, without well-defined ways to represent the processes which the workflow system is supporting.

Purpose: The purpose of this effort would be to demonstrate the viability of a heuristic business-process representation that would be analogous to a current heuristic manufacturing-process representation. The approach should support the representation of business processes, including the Air Force R&D process, in commercial, network-enabled workflow applications. The objective is to substantially reduce the cost and complexity of implementing improved business process support, control, and improvement strategies across enterprises of any scale.

Level of Effort and Timing: The recommended timing and level of effort (in person-hours) for this program are as follows.

	<u>FY97</u>	<u>FY98</u>	<u>FY99</u>	<u>FY00</u>
Person-Hours	350	6500	6500	4000
Deliverables	Plan/Strategy	Draft Semantic	Semantic	Demonstration

3.3.5.2 Recommendation 2: Enterprise Integrated Workflow (EIW).

Background: A key defense concern today is to maintain an adequate defense manufacturing capability in the face of declining defense budgets and low-volume, time-delayed acquisition schedules. A number of strategies are emerging to attempt to address this problem. The Lean Aircraft Initiative (LAI) and its extension to the supplier base, the Lean Supplier Initiative (LSI), are two of the more promising approaches to ensuring a defense industrial base sufficient to meet a wide range of potential threats. LAI and LSI are exploring the application of the principles of Lean Manufacturing, which have been successful in the commercial domain, to the defense manufacturing environment; in particular, to airframe manufacturing. The focus of much of this activity is on business process improvement. The tools to support these new business processes in the defense domain are immature, and workflow tools that are being developed to support commercial enterprises are often not appropriate.

Purpose: Explore, demonstrate, and measure the benefits of using network-enabled workflow tools to support enterprise integration throughout the defense prime-supplier value chain. Determine the required functionality of workflow tools to support business process improvement in that environment, the appropriate metrics to measure that improvement, and the special needs imposed by the nature of defense manufacturing.

Level of Effort and Timing: The recommended timing and level of effort (in person-hours) for this program are as follows.

	<u>FY98</u>	<u>FY99</u>	<u>FY00</u>	<u>FY01</u>	<u>FY02</u>
Person-Hours	2000	10000	10000	8000	5000
Deliverables	Strategy & Metrics	Progress Repts & BPR Functional Specification	Preliminary Demonstration	Complete Functional Specification	Demonstration & Final Technical Report

3.4 (Design)Value Analysis

One of the hurdles in applying IPPD to new technology development is quantifying impact of critical design or architecture decisions on transition cost and risk. The objective of value analysis is to enable the quantification of the cost, risk, and relative value of competing technologies (or design/architecture alternatives). In the case of S&T, it also facilitates technology investment and design decisions earlier in the technology development process.

The S&T IPPD value scorecard shown in figure 2 enables the comparison of performance capability, part/supplier capability, process capability, supportability, life cycle cost, and risk in an integrated matrix. As figure 2 suggests, the S&T IPPD value scorecard combines principles from industry (Six Sigma, Motorola, and the Texas Instruments Six Sigma scorecard) and

academia (Prof. R. Kaplan, Harvard, the Balanced scorecard). The objective of the S&T IPPD value scorecard is to enable the credible estimation of the relative value, costs, and risks of new technologies during their development.

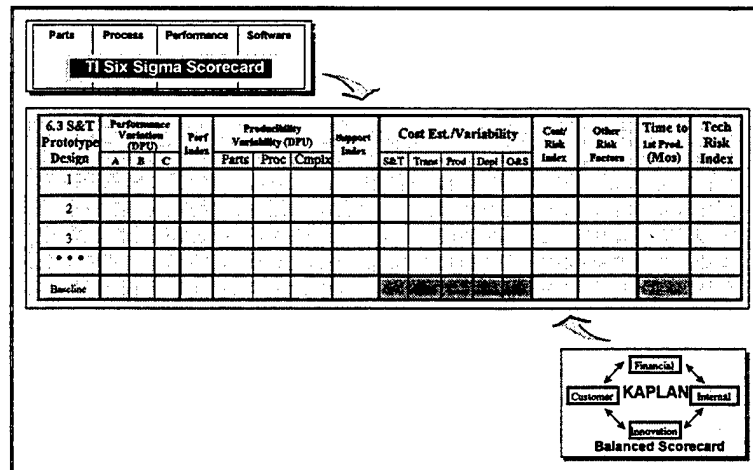


Figure 2. The S&T IPPD Value Scorecard

The difficulty in understanding the needs for tools and methods to support value analysis is that this type of analysis involves many disciplines and many types of tools. Additionally, the methodology for value analysis is still under development. The constellation of tools required depends on the nature of the project. In order to help focus the interview discussions, a scenario was presented which showed how the S&T IPPD value scorecard could be populated from underlying technology (or design) worksheets, as well as how the scorecard could support technology investment decisions. By facilitating the application of a structured methodology, value analysis tools aid in tailoring, then populating the design worksheets and the scorecard.

3.4.1 Interview Results

The interviews for value analysis were handled differently from those for the other three tool areas. As with the other tool areas, participants responded to six warm-up questions following the presentation of the scenario. However, rather than rank and prioritize tools features and functions, the participants were then asked to respond to two focused questions:

1. *Which “pieces” of these IPPD process activities (3&4) might apply to your program(s)? (“Tailor” as required and describe the key functions associated with those “pieces.”)*
2. *What are the tools and methods needed to support those “pieces” or activities?*

Note: Activity 3 involves developing technology alternatives. Activity 4 involves performing the value analysis.

Rationale: the value analysis tool area is sufficiently broad that the participants could not address specific tool needs apart from the context of a specific program or application. A

representative selection of the responses to these questions is provided below, followed by an analysis of the common themes that emerged from them.

What lower level analyses are required to generate scorecard data?

- Analyses for this program include all the “ilities” (reliability, maintainability, deployability, supportability, etc.) as well as basic performance and cost issues. The data ... include ballpark threshold and goal metrics for each aspect of each design.
- I anticipate making very top-level engineering estimates. I do not anticipate running simulations or models in the near term.
- Those yielding excellent knowledge of the concept and its encompassing technologies.
- For selection systems, the capability to identify quality personnel is analogous to system performance. We collect empirical data and conduct statistical analyses on selection systems – ones in use and possible alternatives – to evaluate differences in performance capabilities.
- The different designs come out of people’s knowledge of what’s available that could be used for the purpose. The rest of the data would likely be subjective. We’ve discussed how this process is done subjectively and unsystematically in developing a tutor, so in some sense these factors are subjectively weighed now. I suppose there might be some objective information available some of the time for filling in some of the columns, but I think this would be serendipity and you couldn’t count on it.

What tools do you use to assess the “ilities”?

- For this program, some of the tools will be built into the architecture development tools (such as design rules). In other cases, the “tools” will be a review panel of experts.
- We don’t really use tools for this.
- I’m not aware of any tools to assess the “ilities.”
- There are no tools that I am familiar with to assess the “ilities.” Perhaps the acquisition community should take on the task of providing the labs with this data?
- A bunch of databases about the frequency of field-service failures and the causes for removal-from-service give us our best handle on Reliability and Maintainability (R&M). Vendor data for rejection rate in manufacturing gives us our best shot at quantifying producibility.
- In the current environment, we use none (at least no software tools). The process and procedures to assess reliability, maintainability, skill levels, and Service/Maintain/Replace (SMR) are well known. There are just few formal tools in use (maybe due to lack of availability).

- One tool I use to address reliability issues is MIL HDBK 217, Reliability of Electronic Parts and Systems. There are others.
- Our tools include system-level design tools to define, analyze, and allocate requirements from system to subsystem level. Then, as these subsystems are actually designed, more realistic data is rolled up to ensure the system-level requirements are being met. We use the traditional hardware design tools available commercially today.
- We usually assess the “ilities” qualitatively through past experience and an understanding (educated guess?) of what the issues/drivers will be.
- I agree with the above comment. It is all guess-work based on the person’s vision of the end item and the state of the world in that area of expertise.

How do you estimate and document risks? (List tools.)

- I don’t think we do this in many of our programs.
- It is largely based on experience and technical training. It is largely subjective. Perhaps more time should be spent in this activity.
- Risks ... can be estimated by running simulations of proposed technologies versus real-world test systems. The results will show how well the technology meets the project goals. The risk should surface in the outlying cases where the goals were not met.
- Technological risks are identified by a group of experts.
- Risk estimates are typically based on historical experience with past projects. In my experience, the documentation of program risks has been sparse at this lab. I have seen and worked on other programs that have detailed risk-management plans. They address risks, mitigation efforts, impacts on schedule, etc.
- Informally. The only formal documentation is in the Notes-To-The-Buyer section of a contract award. Our risk estimates are “WAGS” based on gross historical measures. (E.g., has such & such functionality been demonstrated? If so, how stable was it?)

How do you address process capability (manufacturing, software development, training development, etc.) in technology development?

- Right now, we address process capability by expert judgment (i.e., subjectively) and roll that assessment into our judgments on source selection, contract options, etc. There are sufficiently few sources for each technology that a finely tuned assessment is seldom necessary.
- For development of software for selection systems developed under 6.2 and 6.3 programs, process capability is not strictly applicable.

- In the S&T world it is extremely difficult. However, there are a lot of tools used to address process when dealing with EMD/Deployment programs. S&T tries to push the state-of-the-art, and, therefore, introduces more risk. Sometimes these programs highlight where processes are insufficient or need more refinement.
- Informally, not systematically.
- From the past experience of contractors and from previous programs.
- Process capability is very hard to quantify, very subjective. There are a few metrics that are appropriate for each category, but they are not well known or frequently used.
- 6.3 programs address scale-up and repeatability. Often we depend on a manufacturing science or manufacturing technology effort to improve yield and manufacturability.
- In my experience with software systems, processing the capability assessment is still just an "art" -- especially in small and some medium-size companies. The larger companies are still trying to get a handle on their processes program by program. (I don't believe the Capability Maturity Model hype & bravado.) As for training development, it's not just an art, it's a "black" art.

What might keep you from collecting data to populate these scorecards?

- You need readily available sources for this data. If the data are too hard to collect, then they will not be used. It seems the scorecard approach is only as good as the input data.
- Cost is an issue. How much does it take to complete the full analysis?
- Nothing in theory, as long as you make a point of trying to get it. Some information might be more problematical or subjective than other information.
- It is hard to envision how we could use these trade-off tools when we can't envision what the trade-offs could be ahead of time; i.e., we can't specify the tradeoffs, contractually. Also, it is natural that the contractor will select the design that he thinks is the easiest or cheapest to implement. The bottom line is that usually only the contractor has the data to populate the scorecards; we don't.
- I don't see a problem in getting this information. In my program when beginning development of the prototype, the contractor went through trade-off analyses to select the best design approach. Yes, the contractor has the information to do the scorecards, and we have every right to access it. Also, you are in control to select the best method for implementation ... the more systematic a way to do this as manager, the better.
- I think you can always make an educated guess about each data element. But, issues such as proprietary technologies may keep you from entering the best data for a good analysis of the proposed design.

- In some 6.3 and certainly in the 6.2 programs, ignorance is the biggest barrier. Usually the focus of the 6.2 programs is to collect this data on a specific technological approach. This means the analysis tools would be most accurate at the end of 6.2 programs - if each program produced the data in a consistent format.
- The historical ways of doing business for many of our vendors, suppliers, and subcontractors have never included methods which produce the data needed to populate these scorecards. The trick is going to be ramping up each of these organizations to the point where they will produce the required scorecard data.
- The whole idea is wonderful as a concept. However, many concepts can't go beyond this stage due to political and other real-world requirements. I agree with the comments earlier in the day that said this should be done early: either prior to the 6.3 contract award, or as part of a phased or delivery-order approach to the 6.3 effort. However, the money and time required to gather the data and perform this analysis may be difficult to find. Assuming sufficient people, money, and time, I can't see a technical reason why this couldn't be done on any program if the project leader is given the required freedom.

Did the demonstration enable you to understand value analysis and how it could be implemented in the S&T IPPD process?

- Well, it started to. I understand the concepts as they apply to manufacturing and I can think of several ways of estimating (actually "SWAGing") the numbers for our stuff. Again, we hope our decisions are based on something better than throwing a dart. If so, we can find ways to put it in a scorecard.
- The demonstration was very instructive. However, generalization to S&T areas other than hardware and software will take time "to catch on."
- Yes, the demonstration did describe how I could use value analysis. The question remains regarding where I draw the information. My own answer to this is personal knowledge. I would get a better feel for the method by performing an evaluation.
- Based upon this demonstration, I understand the applicability of the value scorecard and how one determines the index of technical risk. I think they would definitely be beneficial. At a high level you could identify the tradeoffs between the different parameters. The lower level data could be captured in other places (or even linked).
- I got some understanding of the process. But, I haven't the faintest idea how we are going to come up with some of the estimates in the scorecard, especially for the important issues of producibility and reliability'
- I've got at least a superficial understanding, but I fear the process is subject to the usual weakness of numerical evaluation matrices: the process of generating the entries (in this case, for the "defect rates") is frequently subjective, despite the appearance of objectivity.

3.4.2 User Needs for Value-Analysis Tools

The tool needs were collected via responses to two questions. The questions and their responses follow.

Question 1: Which "pieces" of these IPPD process activities (3&4) might apply to your program(s)? ("Tailor" as required and describe the key functions associated with those "pieces.")

- I think that both pieces would fit my programs. I do both of these steps now.
- I think all the pieces could be applied. I just think it would take some effort and fumbling to figure out how. A lot might be subject-matter-expert "SWAGs" and a lot might be just plain wrong, but it's worth trying. We could figure it out pretty well, and be better off than we are now.
- Both pieces would help me with project continuity -- to explain past decisions to new representatives of my customers and of my chain of command. If the data were available on-line to my customers and chain of command, I might be able to spend less time explaining decisions and describing issues. Both pieces would help ensure smoother and more cost efficient transition of my products from 6.3 to 6.4, then to the user.
- Both pieces could apply as presented in the briefings. We presently do them differently than briefed, relying more on softer approaches than on statistical analyses, etc.
- I believe that many of the pieces are applicable. I like the concept of including factors pertaining to performance, producibility, and cost in the decision. I like the way the methodology leads you through these data collection and analysis efforts. I'm a little concerned about the "goodness" of the data I will put into the process. From my experience, I would tend to use the "develop technology alternatives" activity immediately. The "perform value analysis" activity would take more effort to learn to apply correctly.
- My view of IPPD is as a tool. From my experiences and discussions with different contractors, technology alternatives are always addressed. The design worksheet is just one tool that can capture the essence of why one design "passed muster," while others did not. It adds an additional level of traceability and corporate knowledge.
- It will be difficult to manage the many different concepts and potential technologies that could fit into the overall program. There could be two or three technologies that support each aspect of an architecture concept and each needs to be considered. This aspect of the program will make it more complicated to come up with the worksheet cards to be used in activities 3 & 4.

- Development of the information that becomes the columns and rows in the worksheets is an intrinsic part of the program's phase I. In general, no serious tailoring should be needed. For the scoring process, the scorecard approach might be difficult to implement completely since some of the uncertainties might be very large and some of the negative interactions might not be fully characterized. Scoring is part of the downselect process, but "a "final grade" might be more appropriate for the program's phase II.
- All of these activities will be applied in this program. The specific methodologies, tools, and processes you presented offer several alternatives for performing the required analyses. Ultimately, it will come down to human judgment; but any tools and structured processes would help to make the overall effort more beneficial and would aid our ability to reconstruct the data. (I.e., another group conducting a similar analysis will come up with similar results.) In the long run, being able to reproduce the results and understand the "logic measures" that went into a study would be the best way to ensure acceptance of the study results. The process would also allow for re-use of information that is appropriately maintained, and for easier adaptation of the results to changing needs and changing technologies.
- Right now I am planning research concerning development of a personnel test to help select operators for unmanned aerial vehicles. I am considering three alternatives in my rough design: a printed selection test, a computer-administered selection test, and a computer-administered job-sample test. Performance (predictive validity, reliability in the psychometric sense), cost, and maintainability could be indexed for these alternatives.

Question 2: What are the tools and methods needed to support those "pieces" or activities?

- The HOQ is an excellent tool with which to start defining technology options and with which to start determining customer needs, but the customer-needs dimension will require relatively more work. Design worksheets and value analysis scorecards would also be useful in the process of determining customer needs. They could be used to show the customers design properties from which to choose, rather than to ask the customers to conjure up details about their needs.
- The pieces could be knowledge of the technologies being applied as well as knowledge of their application. Using a matrix checklist of technology versus application narrowed down the choices.
- A full range of tools could be applied to various aspects of the process. Part of the value added is to determine what current tools exist and how they could be applied. However, the focus of this project (ISCP) is toward future technology results. Having the S&T IPPD members as partners in the process will add the value of addressing process issues on S&T programs while improving the quality and reproducibility of the data obtained.

- There will be a lot of engineering trade studies performed to select the COTS hardware and software. As mentioned earlier, there are lots of available software packages. Selecting those packages that meet the program's functional requirements will be a challenge.
- I want easy-to-use tools, not ones that are too complex. I'm looking for tools that minimize manual data movement and automatically fill in the data where needed. Spreadsheet-based tools are the way to go initially. The tools should use the data you have at the time and allow you to proceed with an assessment. Then, as you get more data, the tools should allow you to enter them and see their impact.
- I am not sure what tools and methods are needed yet. I suppose standard software tools would be applicable to the testing software. But our greatest difficulty concerning new systems is the cost/benefit analysis. "Best value" might not be sufficient.
- We need something simple to minimize its cost and to show the laboratory it benefits programs in the long run. It must maximize the use of existing COTS hardware and software (unless some other organization can provide \$ to help), provide security (such as a point-to-point system with a dedicated server -- the only site on a Web browser), and be easily managed by various participants. My opinion is that we should capitalize on Microsoft products and Web browsers available on the Internet.
- The survey process of tracing the macro needs described in the Mission Area Plans (MAPs) to the detailed technical requirements that supports them is the tool that will be used for supporting both activities. Part of that survey process is not only to identify technical requirements, but also to address the range of acceptable performance levels and the tools that will be most useful to ascertain those performance levels.
- The first tool we will need is a groupware type tool to collect the suggested architectures, allow the group to comment or change the suggestions, and examine the architectures in detail. The next tool we will need is a scoring tool to perform a preliminary analyses of all the suggested architectures. It should take scores from each team member as well as comments regarding scoring rationale. Then, it should combine the scores and output the top three architectures along with the rationale for their selection. We will also need a modeling tool for design alternatives. It will have to analyze the performance metrics and give data about potential pitfalls of the design. It will also have to give first estimates for key engineering parameters and include technological constraints. The final tool we will need is a document generation tool. This tool would allow us to collectively prepare the two reports in the study. It must provide configuration management and restricted access for proprietary information.
- I think guidelines should be developed to itemize as many factors as possible that

contribute to risk, and various algorithms should be proposed for arriving at a single risk factor. I think this would be a very complicated exercise, but it would provide valuable food for thought for those evaluating risk.

3.4.2.1 Value Analysis Participant Feedback: General Observations

The following general observations, concerning value analysis and value scorecard tools, are based on the above comments plus informal feedback from the participants.

1. Flexibility, that is, the support that these tools provide to enable users to tailor them to specific project needs, is a critical requirement for value analysis tools.
2. The extent to which various “ilities” are considered during S&T varies widely and is dependent on the nature of the technology. It is much harder to understand “producibility” and even “reliability” in some contexts (e.g., an architecture specification, reference model, or training model) than in others.
3. The importance of various “ilities” varies widely and is technology-dependent. For example, long-term reliability is paramount for space-based applications and may not be an issue at all for disposable applications. It may have no meaning for certain areas such as a standards specification.
4. The notion of “quality” in S&T, where the result might be an advanced technology demonstration, is very different than in an industrial, medium-to-high-volume-production environment. It can, therefore, be difficult to think in terms of “defects” in S&T, although in many cases it is effective to do so.

While it has been applied successfully in industrial contexts that are similar to 6.3 S&T, the concept of value analysis in S&T is new and not well defined. It must be employed in actual case studies through the S&T pilots in order to achieve more maturity and to provide a better understanding of how it might reduce transition cost and risk.

3.4.2.2 Major Features of Interest

Six key user needs are documented in table 11. Some of these needs, such as Ease of Use, are standard requirements for all software tools. However, the table suggests some ways to *measure* the extent to which those needs have been addressed in specific implementations.

Table 11. User-Needs Summary for Value Analysis Tools

#	Requirement	Description/Features	How Measured
1	Easy to Use	The overall "look and feel" of the interface should be highly intuitive, follow the Microsoft User Interface Guidelines for Windows applications, contain a complete help system, contain set-up wizards, and eliminate the need for a user manual except for occasional references. It must be self-consistent throughout all screens and modules.	<ul style="list-style-type: none"> • # Hours of training required for effective use by computer-literate personnel. • User feedback and response ratings. • # Hours required for mid-level program managers to set up and modify scorecards and worksheets.
2	"Anytime, Anywhere"	Application modules should support collaboration among geographically distributed IPT members in the development of scorecards, worksheets; and in reaching consensus on scorecard values where historical, test, or experimental data is lacking.	<ul style="list-style-type: none"> • User feedback response ratings on how easily and effectively the PATA components can be used by multiple IPT members over the Internet. • % of functions that can be accomplished over a network.
3	Open Systems on Popular Platforms	<p>The software should be compatible with open systems standards and should run on popular platforms.</p> <p>Integration should be via industry standard and popular protocols including OLE and MAPI</p> <p>Clients should be platform-independent since applications are accessed via a Web browser interface. Applications should support all major browsers which, in turn, run on all major platforms including Windows PCs, Macintoshes, and UNIX systems.</p> <p>Server applications and control should be built on a Windows NT platform running Microsoft's Exchange Server and SQL Server.</p>	<ul style="list-style-type: none"> • Support for major protocols and ease of integration with other applications that support those protocols. • % market-share of the platforms on which the applications and development environment will run.
4	Flexible	<p>The value scorecard and design worksheets should be tailorable to specific program needs.</p> <p>Scorecard columns can be added, removed, or further subdivided. Calculations between the columns, including dependency adjustments, should be fully user-configurable.</p> <p>Worksheet organization and content should be fully user configurable.</p> <p>Links between the scorecard and the underlying design worksheets should be configurable.</p> <p>Scorecard and worksheets should easily provide data to, and accept data from, other applications.</p>	<ul style="list-style-type: none"> • User feedback & response ratings on how easily and effectively the scorecards and worksheets can be configured for specific S&T programs. • User feedback & response ratings on ease of reconfiguring scorecards and worksheets after the initial construction and partial population.

Table 11. (Concluded)

#	Requirement	Description/Features	How Measured
5	Security	<p>Sensitive data should be kept secure over the network via auto and point-to-point private encryption. Support for classified data is not required.</p> <p>Password protection for sensitive areas and applications.</p>	<ul style="list-style-type: none">• Granularity of password and encryption protection capability.• Robustness of password (e.g. encrypted passwords) and other encryption algorithms.
6	Technology Transition Cost and Life Cycle Estimation during S&T	<p>During technology development, the tools should aid in estimating the relative and delta costs to transition the technology to a weapon system acquisition activity.</p> <p>The tools should aid in estimating the delta life cycle cost impacts associated with a new technology.</p>	<ul style="list-style-type: none">• Near Term: Model granularity and fidelity of “as-like” estimates.• Long Term: Agreement between projected and measured values.

3.4.2.3 Recommendations for Future Development

As indicated earlier, value analysis is multidisciplinary and, therefore, involves the integration of a number of different applications. Value analysis does not require a “value analysis tool” but rather a “toolkit” comprised of several core applications and the “middleware” required to interface them to a variety of external applications. The toolkit itself must be flexible, so that new or different applications could be easily incorporated into the suite as required. The middleware must support the integration of tools that capture information from the design process with tools that can support its representation in technology worksheets. It must also support value scorecard organization and tailoring, as well as the interface between the worksheets and the scorecard. That interface is bi-directional. Rolled up values from the worksheets are recorded in the scorecard, and sensitivity analyses performed at the scorecard level must access the underlying worksheet information.

The value analysis activity in the S&T IPPD process is central to establishing a quantitative basis for assessing the relative value of alternative technologies. The bottom line resulting from the scorecard should be an assessment of the cost and risk associated with technology transition from the laboratory to the acquisition community or to the defense industrial base. While the scorecard provides an indication of technology maturity on the basis of that transition cost and risk, there exists today no commonly agreed-on set of metrics or Key Performance Indicators (KPIs) for technology maturity.

Three projects are recommended to support the need for improved tools for value analysis. They include the need for a toolkit, the need for a set of agreed-upon KPIs for technology maturity, and the need to extend the heuristic process capability models developed in the electronics domain to other domains (e.g., mechanical, composites).

3.4.3.1 Recommendation 1: Value Analysis Toolkit

Background: The two key needs of a value analysis toolkit center on application integration and worksheet/scorecard support functions. Application integration is required to bring data together from disparate analyses. In the area of performance, the data might result from calculations, simulations, mathematical models, heuristic models, expert consensus, or other sources. The same is true in the areas of producibility, reliability, supportability, etc. Parametric cost models or other cost modeling techniques might be used to develop transition, scale-up, support, or other life-cycle-cost estimates. (In the case of a new technology, the analyses would focus on the potential impact of the technology on those cost factors should it be implemented, generally yielding a relative or delta cost.) The information from these analyses is captured in various design/technology worksheets. Aside from simple spreadsheets, the "worksheet application" does not exist. A really helpful worksheet application would be a "worksheet assistant" that would provide interactive guidance to the user in terms of worksheet tailoring, understanding the most important factors, capturing the rationale/sources behind the data, and supporting the roll-up to the value scorecard rating. The roll-up function would "tag" its own "audit trail" so that a user could quickly see and understand the contributions to the rolled-up number. It would also generate the "hooks" to enable subsequent "backtracking" and "what-if" scenario development associated with sensitivity analysis.

The other component that is needed in value analysis is a "scorecard assistant" that is analogous to the worksheet assistant just described. The scorecard application would assist users in tailoring the scorecard to their needs. It would provide access to instructions and examples on filling in the scorecard, instructions and examples on sensitivity analysis, statistical and graphical support for analyzing scorecard results, and guidance on using the scorecard as a management/investment decision tool. The scorecard assistant must be able to "talk to" the worksheet assistant. The two must work interactively to support the user in determining the significance of and uncertainties associated with various scorecard values.

Purpose: The purpose of this effort is to develop a prototype value analysis toolkit that will support the AFMC S&T IPPD value analysis activities. This effort would result in a prototype toolkit that is validated against actual S&T projects. The toolkit would be used to demonstrate a quantitative assessment of the relative value of competing technologies using S&T value analysis methods.

Level of Effort and Timing: The recommended timing and level of effort (in person-years) for this program are as follows.

	<u>FY97</u>	<u>FY98</u>	<u>FY99</u>	<u>FY00</u>
Person-Hours	5000	5000	7000	7000
Deliverables	Detailed Design & Concept Demonstration	Worksheet & Scorecard Assistant Design	"Assistant" Development & Demonstration	"Assistant" Evolution & Applications

3.4.3.2 Recommendation 2: Key Performance Indicators (KPIs) for Technology Maturity

Background: One of the fundamental objectives of the AFMC S&T IPPD Initiative is to ensure that the technology which emerges from the end of the technology “pipeline” is sufficiently mature to be cost-effectively transitioned into the target user community. The problem is that there is no common understanding of the notion of “technology maturity” either in S&T or in the acquisition community.

Purpose: The objective of this effort is to work with both academia and industry to develop a set of KPIs that could be used to reliably evaluate the “readiness for transition” of a wide range of technologies emerging from S&T. Ultimately, these indicators should provide potential technology implementers with a credible assessment of the risks associated with using a new technology in a product design and development effort. This effort should address software as well as hardware technologies.

Level of Effort and Timing: The recommended timing and level of effort (in person-years) for this program are as follows.

	<u>FY97</u>	<u>FY98</u>	<u>FY99</u>	<u>FY00</u>
Person-Hours		400	3500	4000
Deliverables		Initial Problem Description & Approach	Initial KPIs for New Technologies	Refined Set of Technology KPIs and Application Examples

3.4.5.3 Recommendation 3: Heuristics-Based Design-Process Simulation Models

Background: Leading companies in the electronics domain have initiated the development of heuristic models that implement new designs in a “virtual build” in order to improve design robustness and producibility prior to their manufacture. These models are more than “design rules.” They relate process capability and expected defects to design features, and provide real-time feedback to designers regarding the implications of various design decisions. These models are only now being fleshed out in the electronics domain for specific families of products, but early indicators suggest that the potential cost and cycle-time savings from employing such models in the design process are enormous.

Purpose: Understand the heuristic modeling approach as it is evolving in the electronics domain, and explore the feasibility of applying the same principles to the airframe and propulsion domains.

Level of Effort and Timing: The recommended timing and level of effort (in person-years) for this program are as follows.

	<u>FY97</u>	<u>FY98</u>	<u>FY99</u>	<u>FY00</u>	<u>FY01</u>
Person-Hours	300	6500	8000	8000	5000
Deliverables		Framework for heuristic models from electronics	Development of models and demo for airframe	Development of models and demo for propulsion	Domain- Independent Framework for Heuristic Models

4. Tools Deployment Strategy

The end-user assessment of the S&T IPPD tool areas revealed that program managers need tools to implement the S&T IPPD process. This assessment also showed that each program is likely to have different needs depending on the nature of the research and the maturity of the technology under development. Needs identified by the participants in the interviews were used to conduct market assessments for each tool area. Recommended deployment approaches were given for each tool area in section 3. In addition to the deployment strategies delineated in section 3, certain activities need to continue throughout the S&T IPPD tools and methods effort. These activities are:

- Minimize the commitment to customize or combine tools until the need is imminent in an S&T program.
- Monitor market developments regarding the key features and capabilities identified by the users during the interviews.
- Seed prototyping software development in the value analysis area since the marketplace is only now recognizing this tool area as a potential product category.
- Encourage and participate in standards development, particularly in the areas of Web-enabled workflow, requirements analysis, and security.
- Form a Tools and Methods Working Group to track, assess, and report on tool and method developments related to the S&T IPPD process.

It is stressed again that this deployment plan is not a software development plan. The intent is to use COTS tools to meet as many user needs as possible before modification is considered.

5. Summary

The primary objective of this effort was to gather user needs for tools and methods to support the implementation of the S&T IPPD process. This report has presented the results of the research conducted for four tool areas: (1) (Technology) Requirements Collection, Organization, and Analysis; (2) Value Judgment via Expert Consensus; (3) (Program Management) Workflow; and 4) (Design) Value Analysis. The research approach was to first interview users to collect and verify user needs for the tools. Next, a market assessment was accomplished to determine if COTS tools exist that fulfill the users' needs. Finally, a strategy was developed for tools deployment throughout the Air Force S&T community.

The user interviews were conducted using Ventana GroupSystems software. The interviews were structured as information-sharing sessions where the research team presented information about which the users were asked to provide feedback and comments. This methodology proved to be effective in capturing and validating needs for a Group Consensus Tool.

Once the user needs were known, a market assessment was conducted. The market assessment showed that there is an abundant supply of tools for all areas except value analysis. This is good news for users since competition will produce more and better tools. Since different users will probably have different tool needs, they can each use the evaluation matrices shown for each tool area to choose a tool based on their particular needs.

This report recommends a tools development strategy for deploying tools throughout the S&T community. As such, this report is not a software development plan, but a strategy for selecting tools, customizing them, and integrating them over time into specific S&T programs having specific objectives. The essence of the strategy is:

- Choose selected pilot programs to implement the S&T IPPD process.
- Minimize the commitment to customize or combine tools until the need is imminent in an S&T program.
- Monitor market development regarding the key features and capabilities identified by users in the interviews.
- Seed prototyping software development in value analysis since the marketplace is only now recognizing this tool area as a potential product category.
- Encourage and participate in standards development, particularly in the areas of Web-enabled workflow, requirements analysis, and security.
- Form a Tools and Methods Working Group to track, assess, and report on tools and methods developments related to the S&T IPPD process.

Follow-on work is necessary to choose, modify, and field tools for 6.3 program managers to use in their everyday activities. This effort should be closely coordinated with the overall IPPD

initiative to maximize benefits for users. The strategy delineated in this report represents the first step in deploying tools and methods to assist program managers in implementing the S&T IPPD process. By employing IPPD principles and practices, the S&T culture can move away from the historic performance-at-any-cost approach to technology development and application, toward a new, more cost-effective and risk-managed approach.